NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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TECHNICAL MEMORANDUM

No. 1146

TEST REPORT ON THREE- AND SIX-COMPONENT MEASUREMENTS ON A SERIES OF TAPERED WINGS OF SMALL ASPECT RATIO

(Partial Report: Elliptic Wing)

By Lange/Wacke

Translation

"3- und 6-Komponentenmessung an der Zuspitzungsreihe von Flügeln kleiner Streckung. Teilbericht: Ellipsenflügel"

Deutsche Luftfahrtforschung, Untersuchungen und Mitteilungen Nr. 1023/3

Washington

June 1947

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TEST REPORT ON THREE- AND SIX-COMPONENT MEASUREMENTS ON A SERIES OF TAPERED WINGS OF SMALL ASPECT RATIO*

(Partial Report: Elliptic Wing)

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INTRODUCTION

The report UM No. 1023/1 which presented the results of measurements for a series of trapezoidal wings was the beginning of a series on wings with aspect ratio 1 to 3 and various contours (fig. 1). In report No. 1023/1 the aspect ratio ($\Lambda = 4/3$) remained the same; the tapering was modified. The present report gives the results of the series of elliptic wings. Here the aspect ratio varies from 1 to 2 with the sweepback. The contour is formed by elliptic arcs. (See fig. 2.)

The influence of sweepback and contour upon the neutral point is shown.

MODELS

The models were made of wood at scale 1:1; the surface was polished. Three wings, identified as EE, $\Lambda = 2$; DE, $\Lambda = 4/3$; CE, $\Lambda = 1$ were used. The dimensions and plan forms are given in figure 2. The elliptic-wing leading edge was produced by the affine distortion of an eighth circle. The airfoil was an NACA 0012 section.

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*"3- und 6-Komponentenmessung an der Zuspitzungsreihe von Flügeln kleiner Streckung, Teilbericht: Ellipsenflügel," Untersuchungen und Mitteilungen Nr. 1023/3. Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters (ZWB). Berlin-Adlershof, Sept. 21, 1943.

APPARATUS AND METHODS

The tests were run in the 3 × 2.15m wind tunnel of the DVL. The models were suspended in the usual manner on the six-component balance. Care was taken to make the suspension conform to the test conditions of the preceding measurement, so as to ensure a good comparison of the results. The dynamic pressure was $q = 100$ kg/m^2 corresponding to 40 m/sec airspeed.

COEFFICIENTS AND SYMBOLS

The forces and moments were measured with respect to the experimental system of axes (fig. 6).

The moment reference point for all three wings lies on the wing chord at a distance three-quarters of the mean reference chord from the wing trailing edge (fig. 2). The reference axes of the moments are defined as follows: (See fig. 6.)

Rolling moment: x_e-axis = line of intersection of the vertical plane of symmetry of the body with the horizontal plane of the tunnel (positive in wind direction).

Pitching moment: y_e-axis = lateral axis along the wing (positive toward the left, seen in wind direction).

Yawing moment: z_e-axis = normal axis in wind direction (positive downward).

All moments are positive when they are in a direction to produce clockwise rotation when looking along the positive direction of the axes.

The coefficients of the forces and moments are:

A lift, kilograms

W drag, kilograms

Q cross-wind force, kilograms

L rolling moment

M pitching moment

N yawing moment

$c_a = \frac{A}{q \times F}$ lift coefficient

$c_w = \frac{W}{q \times F}$ drag coefficient

$c_q = \frac{Q}{q \times F}$ cross-wind force coefficient

$c_L = \frac{L}{q \times F \times \frac{b}{2}}$ rolling-moment coefficient

$c_M = \frac{M}{q \times F \times l_m}$ pitching-moment coefficient

$c_N = \frac{N}{q \times F \times \frac{b}{2}}$ yawing-moment coefficient

Angles:

α = angle of attack — angle between longitudinal axis along the wing and the x_e-axis

β = angle of yaw — angle between the longitudinal axis in wind direction and the x_e-axis

The signs are for a right-hand positive system, clockwise rotation is positive.

Reference quantities:

F wing area, meters^2

b span, meters

$l_m = \frac{F}{b}$ mean chord (reference chord), meters

$q = \frac{\rho}{2} v^2$ dynamic pressure, (kg/m^2)

Λ aspect ratio

Dimensions of models:

Wing EE	Wing DE	Wing CE
$\Lambda = 2$	$\Lambda = \frac{4}{3}$	$\Lambda = 1$
$F = 0.75\ m^2$	$F = 0.75\ m^2$	$F = 0.75\ m^2$
$b = 1.225$ m	$b = 1$ m	$b = 0.866$ m
$l_m = 0.6125$ m	$l_m = 0.75$ m	$l_m = 0.866$ m

RESULTS

A list of the charts and tables is reproduced in table A.

(a) Three-component measurements.- The results are represented in graphs 1, 7, and 13 as $c_a = f(\alpha)$, $c_a = f(c_w)$, and $c_a = f(c_M)$. The effectiveness of c_a' (slope of lift curve) decreases with decreasing Λ as expected. The increasing sweepback from wing EE to CE also acts in the decreasing sense.

At small angles of attack, the neutral point lies forward of the moment reference point; the wing is unstable. This forward position changes to a rearward position at higher c_a values. With increasing aspect ratio and increasing sweepback, the neutral point in the entire c_a range is moved back. The tuft measurements on the triangular wings indicated that the cause of it is attributable to a strong transverse flow in the rear part of the wing, which produces stabilizing lifting forces. With decreasing aspect ratio and increasing taper, the $c_{a_{max}}$ reaches a maximum value at $\Lambda = 4/3$,

where $c_{a_{max}}$ shifts toward higher angles of attack. Conspicuous is the sharp separation of flow on the wing $\Lambda = 2$, and the very flat curve in the range of $c_{a_{max}}$ on the other two wings. This is mainly due to the sweepback, through which the additional velocity over the wing is substantially diminished.

(b) Six-component measurements.- The coefficients of the six-component measurements are presented with respect to the angle of yaw β and the angle of attack α as parameter. The effect of the yawed flow on lift, drag, and pitching moment is small on all three wings. The cross-wind force is the same as on wings with large aspect ratio. At small α a positive rise in cross-wind force with increasing β is observed, principally due to the form drag of the leading-wing leading edge. It is greatest at the wings with least sweepback (wing EE). At greater angles of attack the negative cross-wind force of the wing predominates. The cross-wind force curve of DE, $\Lambda = 4/3$, deviates from this variation at $\alpha = 35.47^\circ$ ($c_{a_{max}}$).

The rolling moment increases with sweepback as a result of the transverse flow in the rear part of the wing.

The yawing-moment variation with the angle of yaw is negative for all three wings. With increasing angle of attack, the directional stability increases. This is also dependent upon the form drag of the leading edge of the wing.

ADDITIONAL REPORTS OF THE SERIES

	UM NO.
Trapezoidal wing ($\Lambda = 4/3$)	1023/1
Trapezoidal wing with fuselage	1023/2
Elliptical wing with fuselage	1023/4
Triangular wing ($\Lambda = 3 - 1$)	1023/5
Triangular wing with fuselage	1023/6

Voepel, DFS, of the firm of Henschel, Schönefeld, is preparing a summary of all results of this series of measurements taking the theory of wings of small aspect ratio into consideration.

Translated by J. Vanier
National Advisory Committee
for Aeronautics

TABLE A

SURVEY OF THE THREE- AND SIX-COMPONENT MEASUREMENTS ON THE SERIES OF TAPERED WING (ELLIPTIC WING)

Symbol	Angle		Chart of curves	Table
	α°	β°		
EE $\Lambda = 2$ Three-component measurement	Variable	0	1	1
EE $\Lambda = 2$ Six-component measurement	0	Variable	2	2
EE $\Lambda = 2$ Do----	6.84	---do---	3	2
EE $\Lambda = 2$ Do----	13.87	---do---	4	3
EE $\Lambda = 2$ Do----	20.51	---do---	5	3
EE $\Lambda = 2$ Do----	23.79	---do---	6	4
DE $\Lambda = \frac{4}{3}$ Three-component measurement	Variable	0	7	5
DE $\Lambda = \frac{4}{3}$ Six-component measurement	0	Variable	8	6
DE $\Lambda = \frac{4}{3}$ Do----	9.43	---do---	9	6
DE $\Lambda = \frac{4}{3}$ Do----	17.95	---do---	10	7
DE $\Lambda = \frac{4}{3}$ Do----	25.89	---do---	11	7
DE $\Lambda = \frac{4}{3}$ Do----	35.47	---do---	12	8
CE $\Lambda = 1$ Three-component measurement	Variable	0	13	9
CE $\Lambda = 1$ Six-component measurement	0.4	Variable	14	10
CE $\Lambda = 1$ Do----	11.73	---do---	15	10
CE $\Lambda = 1$ Do----	21.36	---do---	16	11
CE $\Lambda = 1$ Do----	30.30	---do---	17	11
CE $\Lambda = 1$ Do----	38.63	---do---	18	12
Comparative curves of the three wings				
$c_a = f(\alpha)$; $c_a = f(c_w)$	Variable	0	19	
$c_a = f(c_M)$	Variable	0	20	
c_L and $c_q = f(\beta)$	$\alpha_{c_a} = 0.3$	Variable	21	
c_L and $c_q = f(\beta)$	$\alpha_{c_a} = 0.9$	Variable	22	

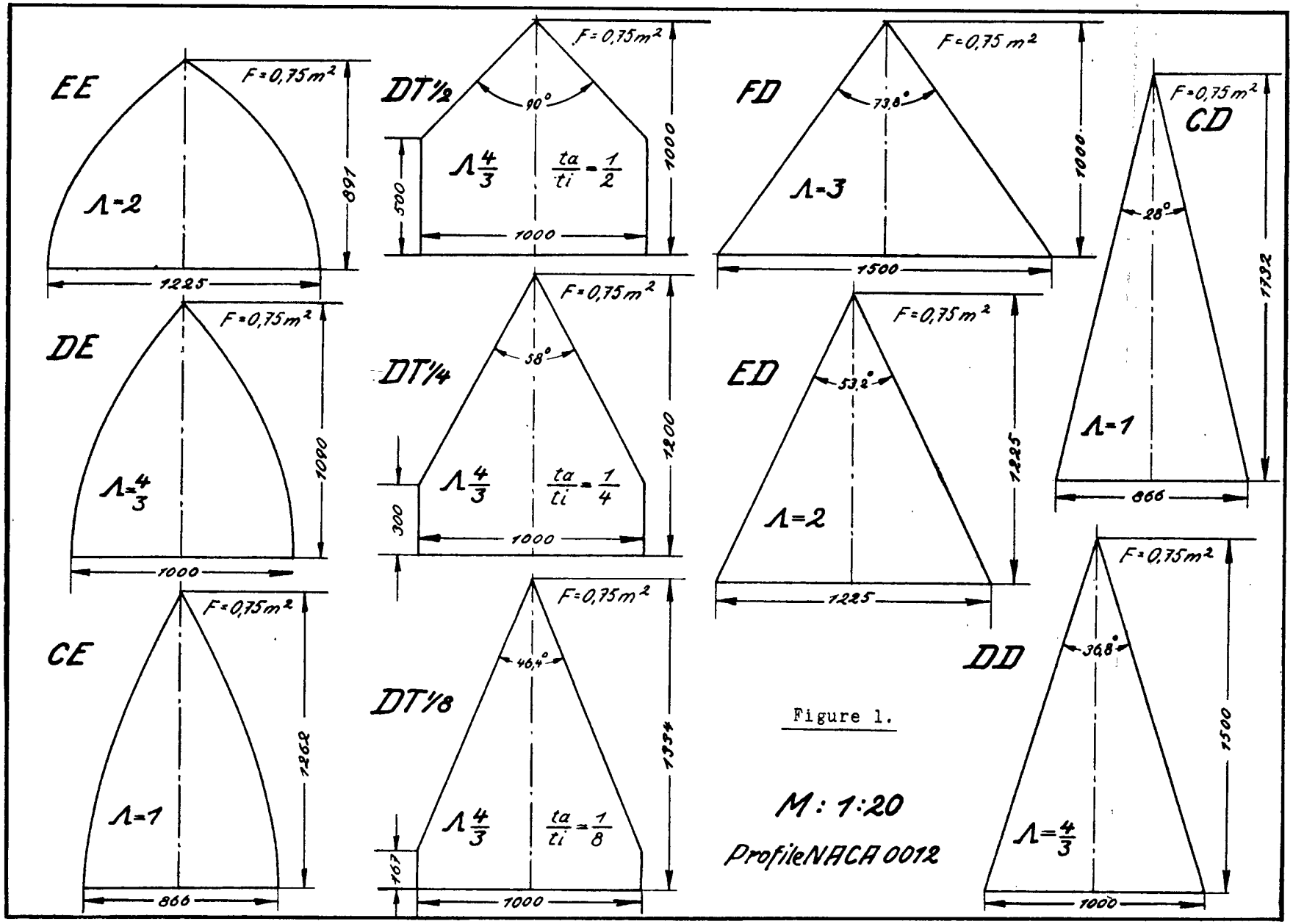


Figure 1.

M: 1:20

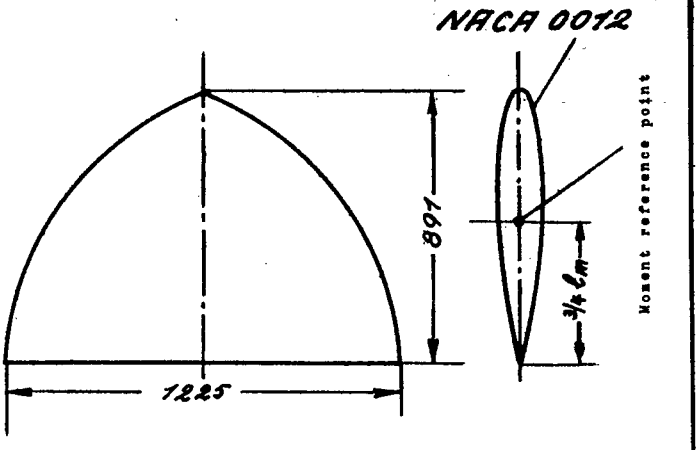
Profile NACA 0012

Fig. 1

Figure 2.
Elliptic wing

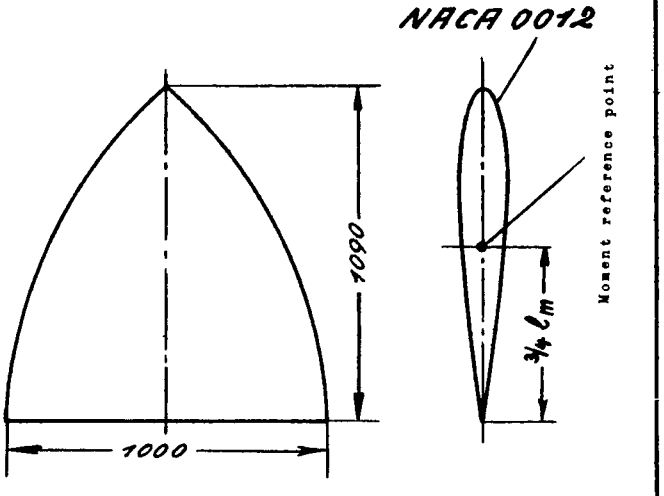
EE

$\Lambda = 2$
$F = 0{,}75\,m^2$
$b = 1{,}225\,m$
$l_m = \frac{F}{b} = 0{,}6125\,m$



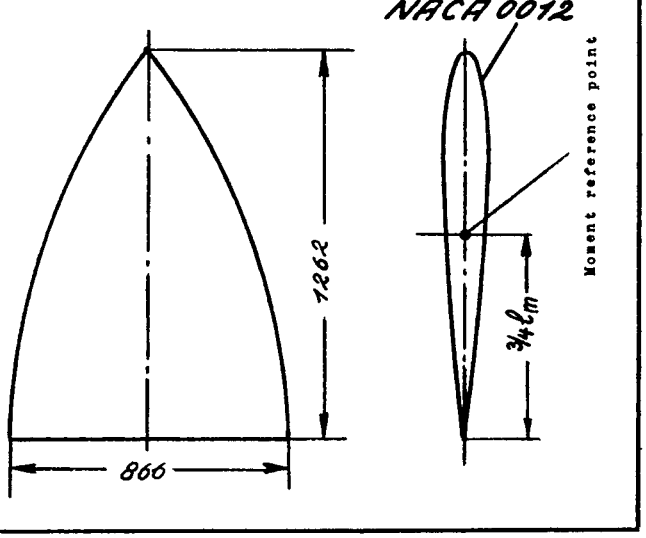
DE

$\Lambda = \frac{4}{3}$
$F = 0{,}75\,m^2$
$b = 1\,m$
$l_m = \frac{F}{b} = 0{,}75\,m$



CE

$\Lambda = 1$
$F = 0{,}75\,m^2$
$b = 0{,}866\,m$
$l_m = \frac{F}{b} = 0{,}866\,m$



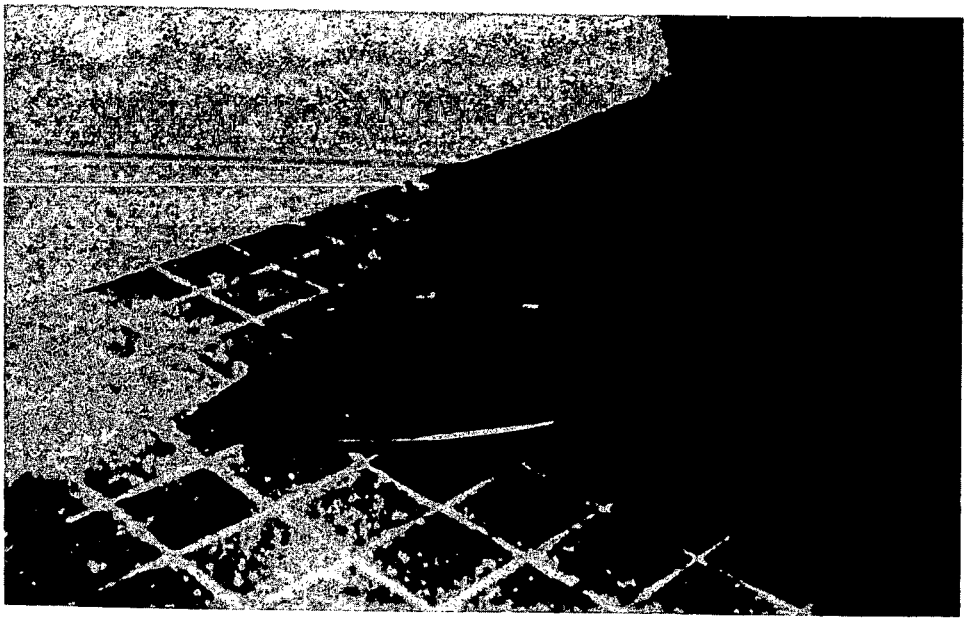


Figure 3.
Wing EE, $\Lambda = 2$

Figure 4.
Wing DE, $\Lambda = 4/3$

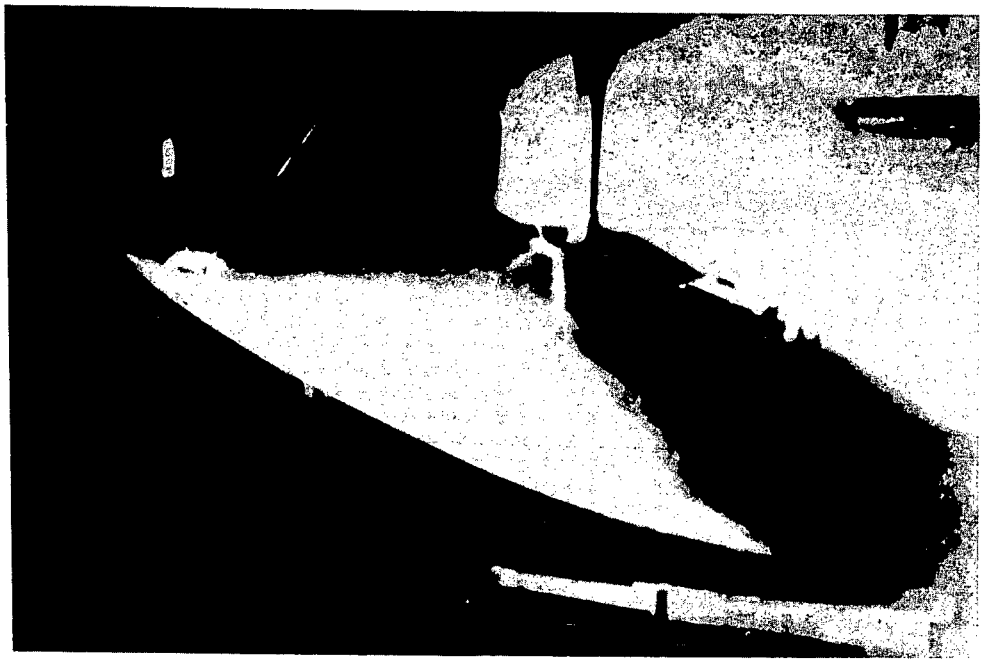


Figure 5.
Wing CE, $\Lambda = 1$
in 2.15x 3m windtunnel

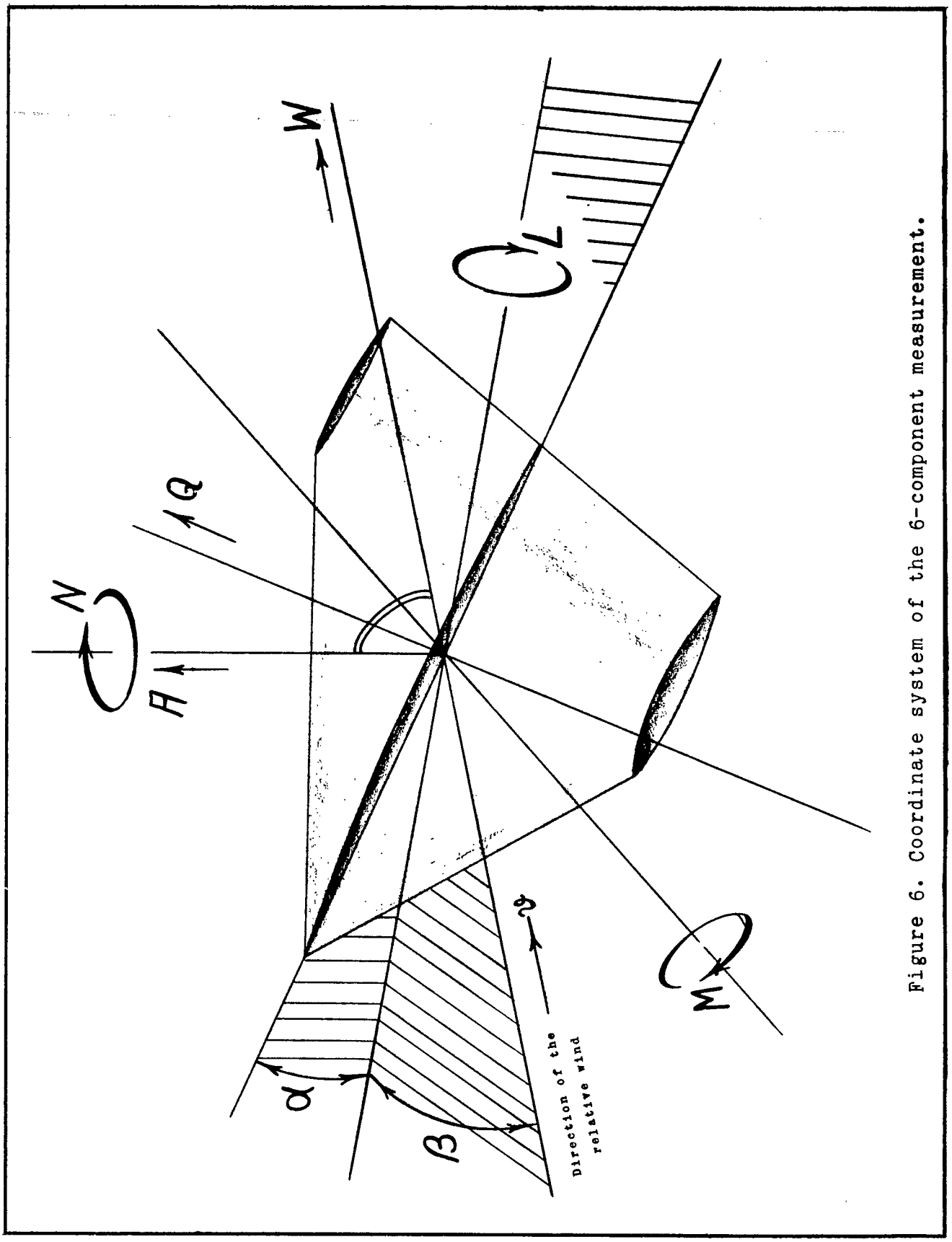


Figure 6. Coordinate system of the 6-component measurement.

THREE-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WINGS
(Elliptic Wing)
TABLE NO. 1 TO CHART 1
EE, $\Lambda = 2$

α°	c_a	c_w	c_M
-5.70	-0.2412	0.0175	-0.0176
0	0	.0061	.0009
5.69	.2480	.0180	.0188
11.39	.4950	.0502	.0321
17.08	.7460	.1067	.0343
19.91	.8790	.1515	.0309
22.75	1.0110	.2097	.0227
23.70	1.0520	.2323	.0225
24.17	1.0780	.2429	.0203
24.64	1.0990	.2560	.0193
25.10	1.12-1.135	.3285	.0201
25.82	0.947-0.966	.4182	-.0049
26.94	0,827-0,88	.4273	-.0191
0	.0027	.0060	.0013

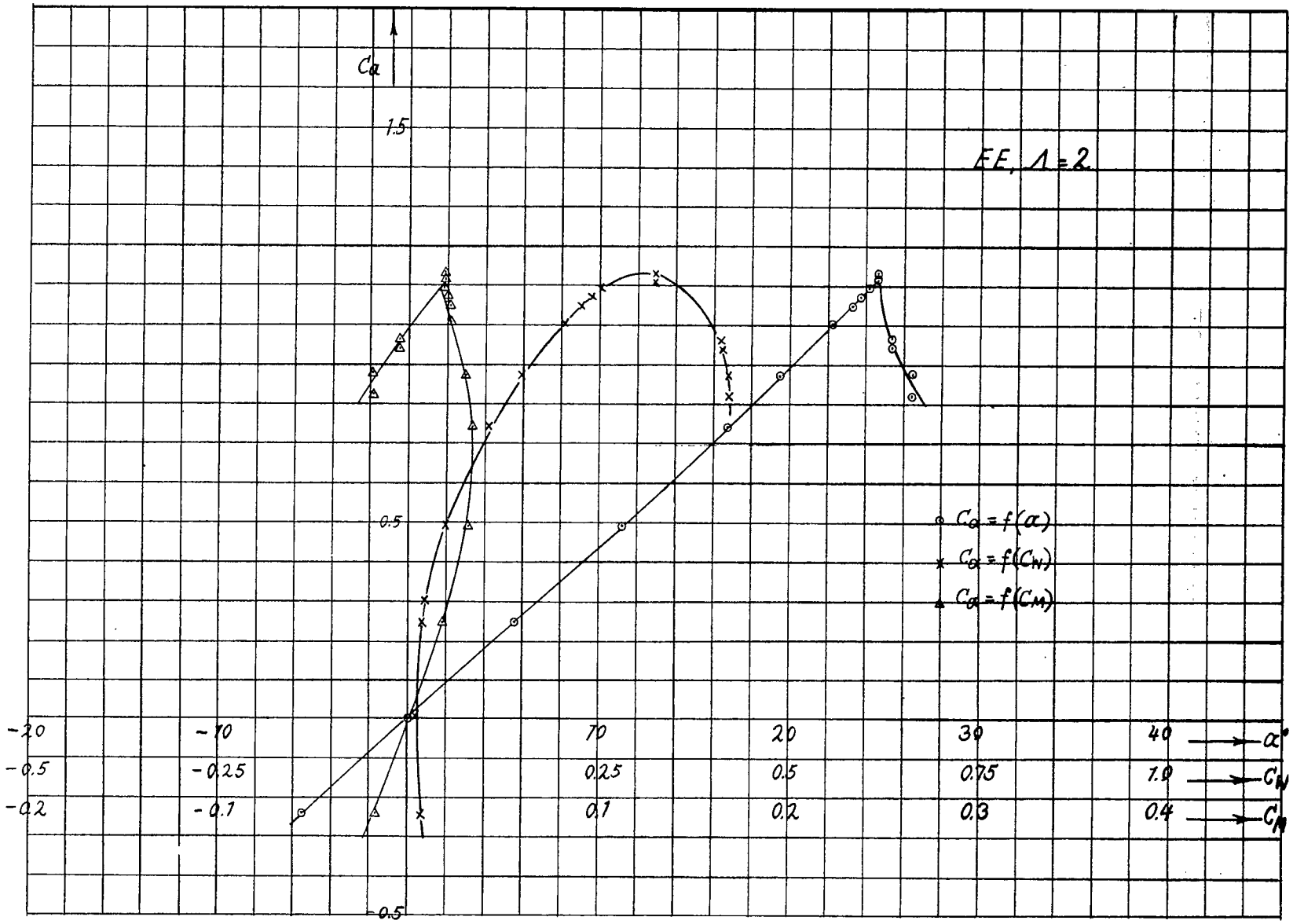


Chart 1. 3 - component measurements of a series of tapered wings (elliptic wing)
Table 1.

SIX-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WINGS

(Elliptic Wing)

TABLE NO. 2 TO CHARTS 2,3

EE, $\Lambda = 2$

$\alpha = 0$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.0030	-0.0020	0.0063	0	0.0014	0.0020
-2	.0030	-.0013	.0063	-.0001	.0014	.0007
0	.0030	0	.0063	0	.0014	0
2	.0030	.0013	.0063	.0001	.0014	-.0010
4	.0030	.0027	.0063	0	.0014	-.0021
6	.0030	.0033	.0063	.0001	.0014	-.0026
10	.0030	.0047	.0072	.0009	.0014	-.0036
15	.0030	.00600,	.0081	.0010	.0014	-.0053
20	.0030	.0080	.0093	.0017	.0015	-.0062

EE, $\Lambda = 2$

$\alpha = 6.84^\circ$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.2960	-0.0020	0.0221	-0.0128	0.0220	0.0041
-2	.2960	-.0013	.0223	-.0060	.0221	.0024
0	.2960	-.0007	.0221	0	.0230	.0003
2	.2960	.0007	.0221	.0069	.0224	-.0021
4	.2960	.0013	.0221	.0129	.0221	-.0035
6	.2940	.0013	.0221	.0197	.0223	-.0046
10	.2860	.0017	.0222	.0304	.0226	-.0076
15	.2740	.0023	.0226	.0448	.0216	-.0111
20	.2620	.0030	.0227	.0569	.0199	-.0140

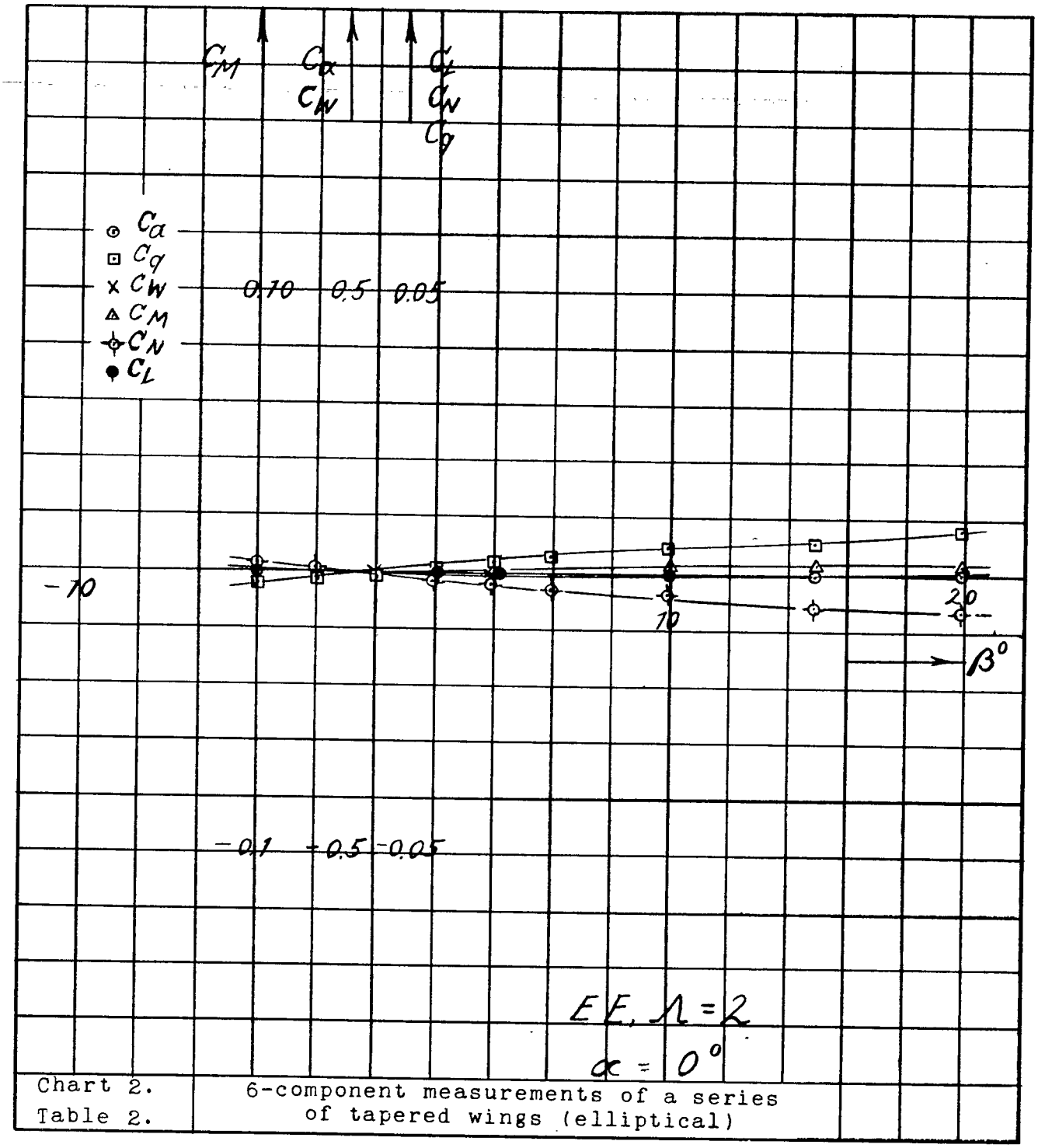


Chart 2.
Table 2.

6-component measurements of a series of tapered wings (elliptical)

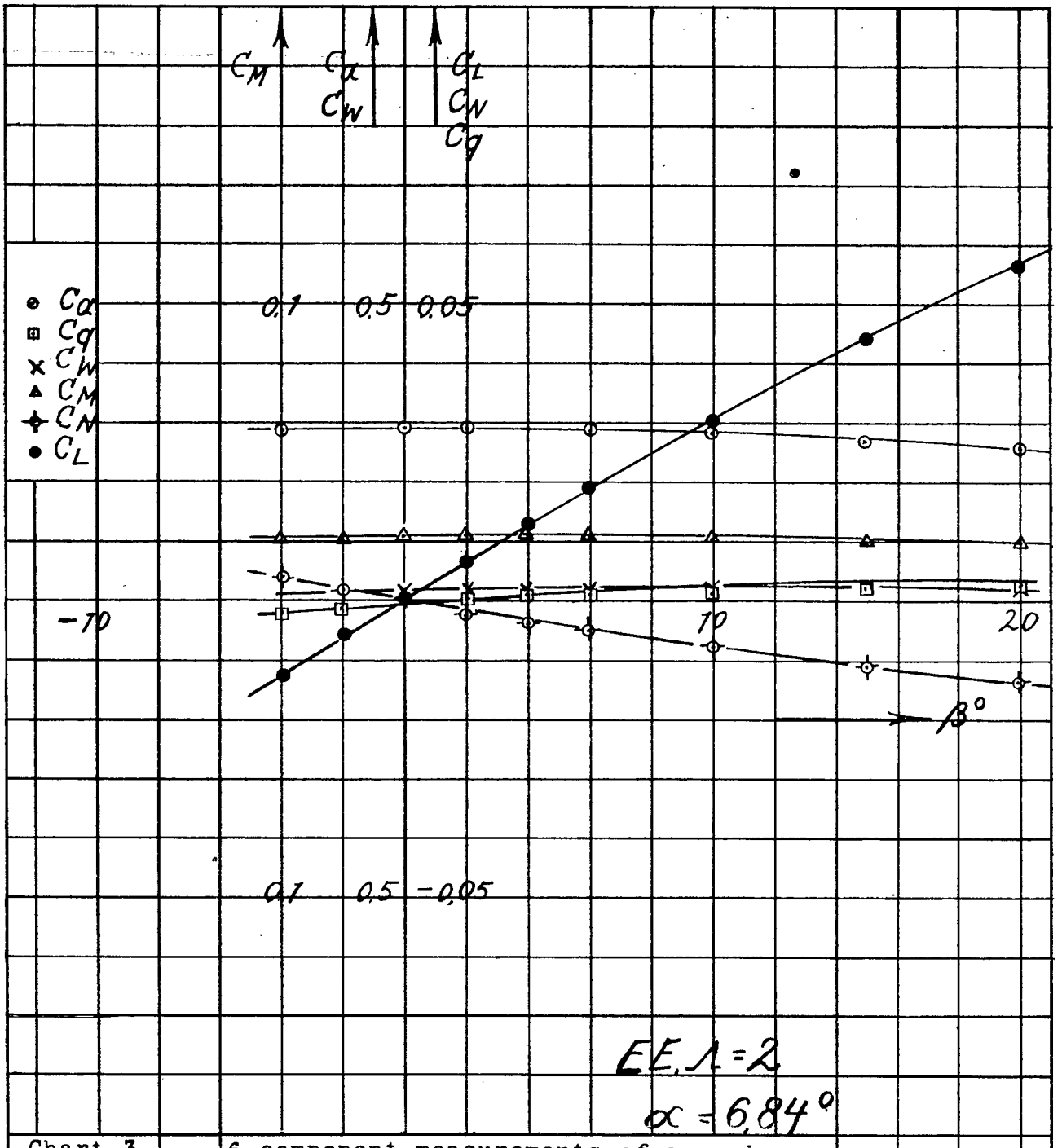


Chart 3.
Table 2.

6-component measurements of a series of tapered wings (elliptical)

SIX-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WINGS

(Elliptic Wing)

TABLE NO. 3 TO CHARTS 4, 5

EE, $\Lambda = 2$

$\alpha = 13.87°$

$\beta°$	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.601	0.0027	0.0731	-0.0219	0.0340	0.0081
-2	.602	.0013	.0732	-.0098	.0347	.0040
0	.604	.0003	.0730	.0015	.0346	-.0002
2	.602	-.0013	.0731	.0136	.0347	-.0049
4	.600	-.0027	.0730	.0235	.0341	-.0081
6	.596	-.0047	.0726	.0348	.0344	-.0110
10	.585	-.0087	.0712	.0554	.0334	-.0171
15	.564	-.0147	.0692	.0799	.0320	-.0241
20	.536	-.0186	.0674	.1004	.0300	-.0307

EE, $\Lambda = 2$

$\alpha = 20.51°$

$\beta°$	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.903	0.0107	0.1642	-0.0265	0.0275	0.0116
-2	.904	.0067	.1643	-.0123	.0284	.0046
0	.905	.0020	.1643	.0014	.0289	-.0022
2	.905	-.0040	.1644	.0136	.0289	-.0070
4	.901	-.0113	.1645	.0274	.0293	-.0118
6	.896	-.0180	.1639	.0405	.0288	-.0166
10	.884	-.0346	.1623	.0674	.0277	-.0240
15	.850	-.0286	.1688	.0858	.0280	-.0487
20	.794	-.0366	.1623	.1056	.0279	-.0604

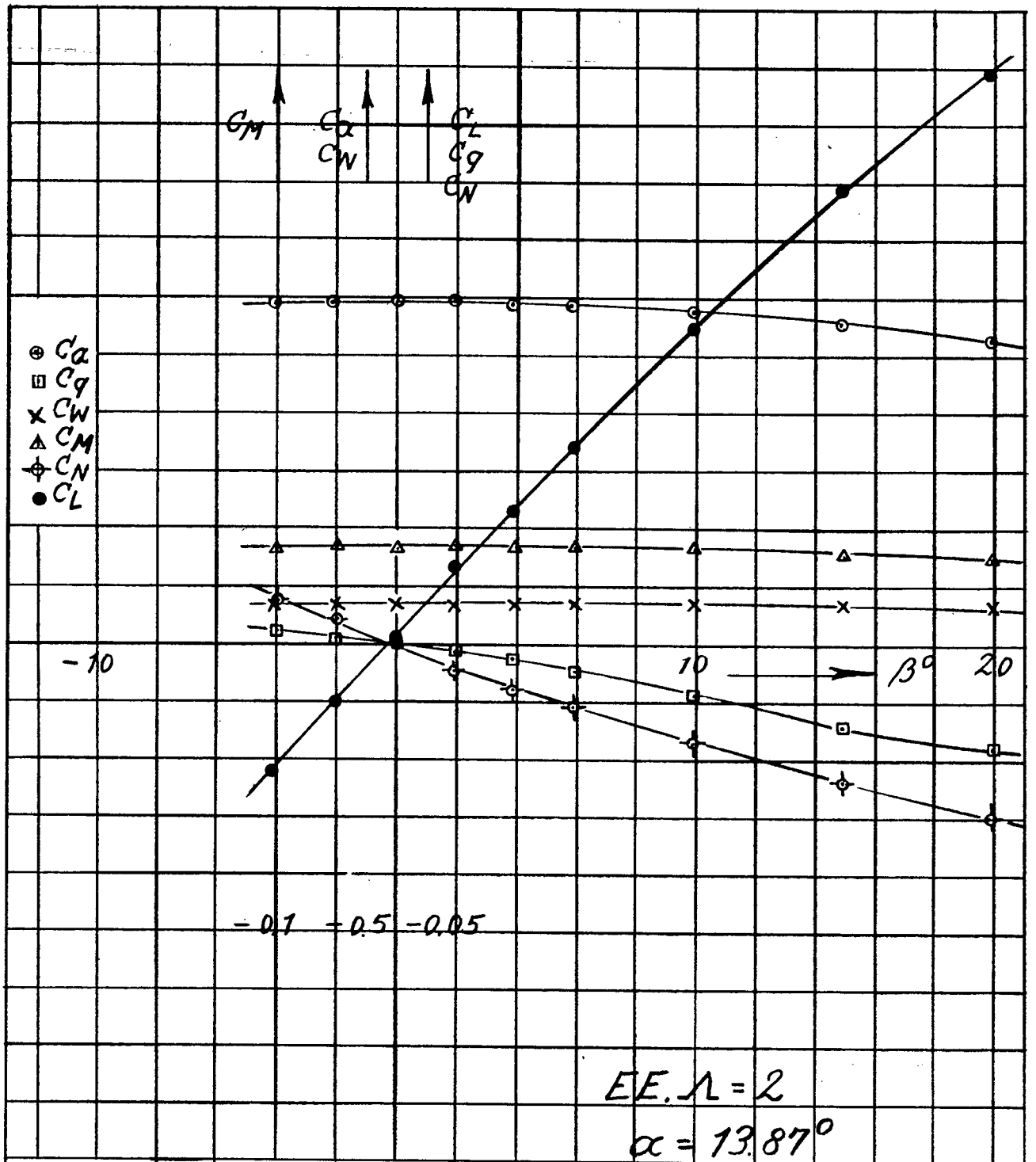
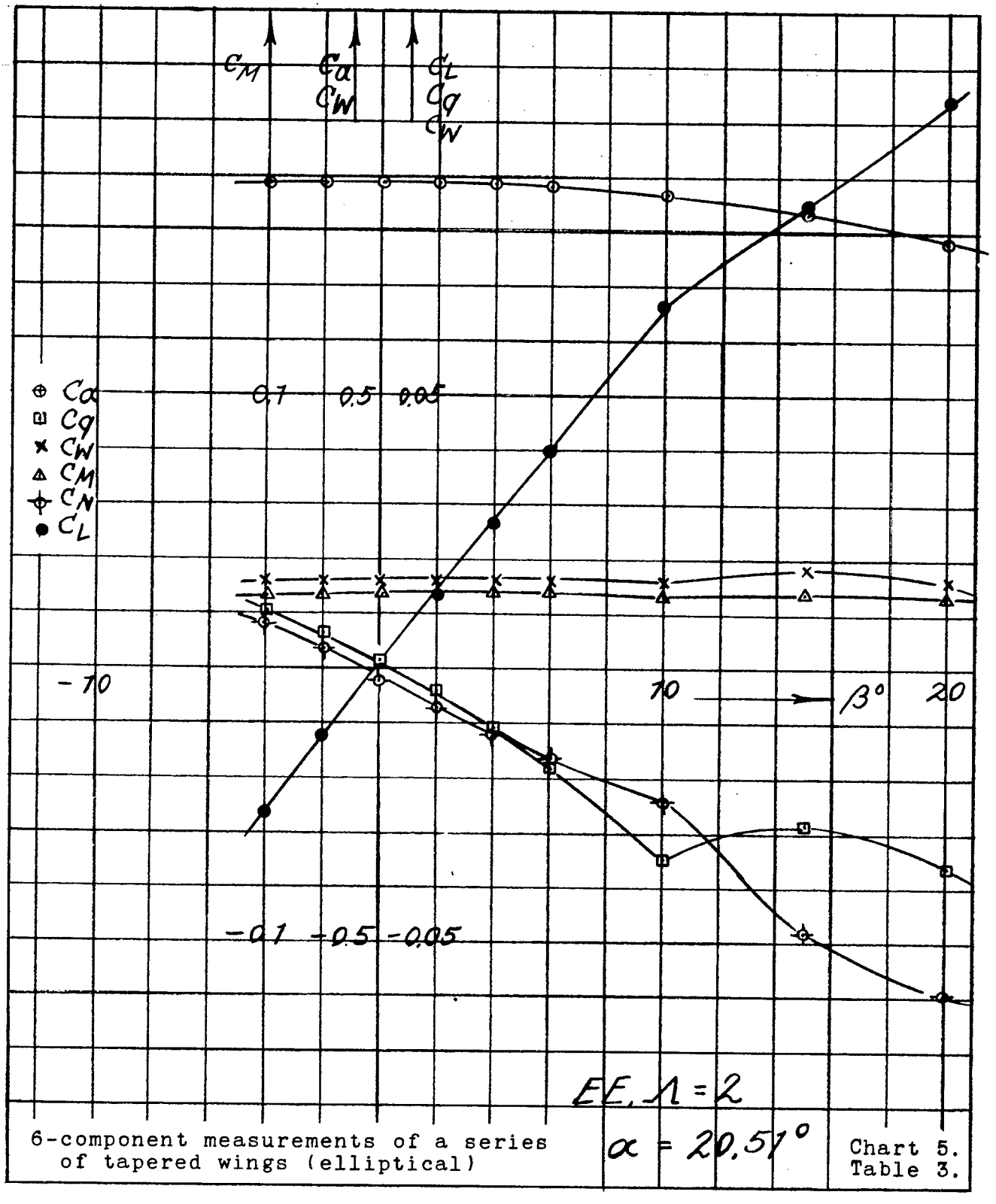


Chart 4.
Table 3.

6-component measurements of a series of tapered wings (elliptical)



6-component measurements of a series of tapered wings (elliptical)

Chart 5. Table 3.

SIX-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WINGS

(Elliptic Wing)

TABLE NO. 4 TO CHART 6

EE, $\Lambda = 2$

$\alpha = 23.79^\circ$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	1.050	0.0120	0.2322	-0.0302	0.0208	0.0176
-2	1.051	.0073	.2317	-.0167	.0207	.0083
0	1.052	0	.2320	-.0008	.0209	-.0008
2	1.054	-.0060	.2331	.0144	.0206	-.0092
4	1.051	-.0127	.2351	.0279	.0211	-.0178
6	1.045	-.0160	.2384	.0390	.0217	-.0279
6	.965	.0746	.3012	-.0492	.0119	-.0239
10	.898	.0546	.2998	-.0455	.0046	-.0213
15	.831	.0300	.2856	-.0165	.0046	-.0314
22	.808	-.0100	.2607	.0283	.0168	-.0488

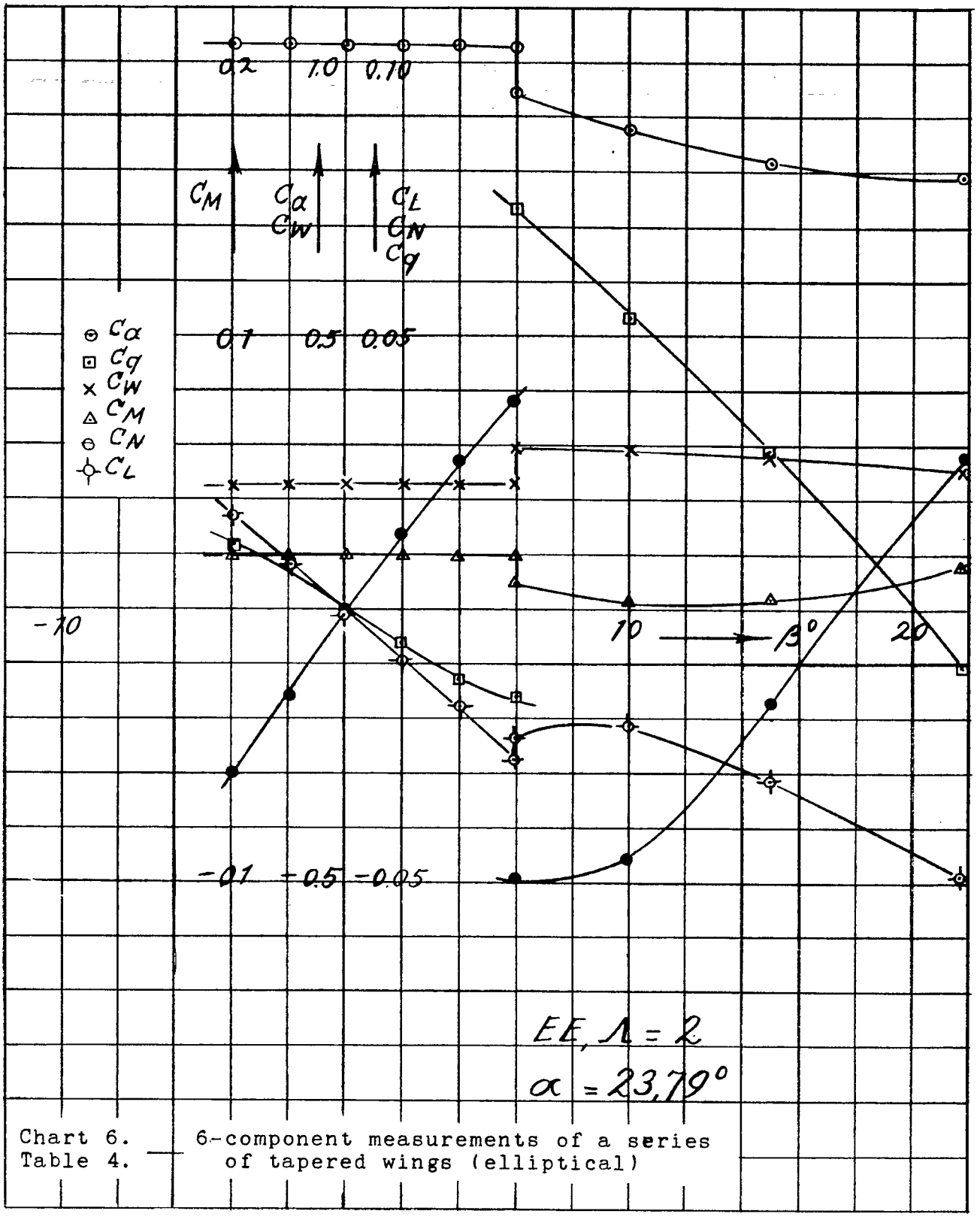


Chart 6. Table 4. — 6-component measurements of a series of tapered wings (elliptical)

THREE-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WING

(Elliptic Wing)

TABLE NO. 5 TO CHART 7

DE, $\Lambda = \frac{4}{3}$

α^o	c_a	c_w	c_M
-5.66	-0.1880	0.0144	-0.0131
0	0	.0053	-.0001
5.77	.1800	.0144	.0135
11.52	.3750	.0448	.0181
17.27	.5740	.0982	.0115
22.99	.7940	.1894	-.0005
28.99	1.0050	.3136	-.0349
31.58	1.1020	.4019	-.0566
34.48	1.2030	.5068	-.0695
35.39	1.2750	.6592	-.0662
36.37	1.2890	.6986	-.0632
37.37	1.2950	.7383	-.0677
35.43	1.2450	.5662	-.0725
36.35	1.3080	.6979	-.0671
37.33	1.3220	.7367	-.0693
38.42	1.2540	-	-

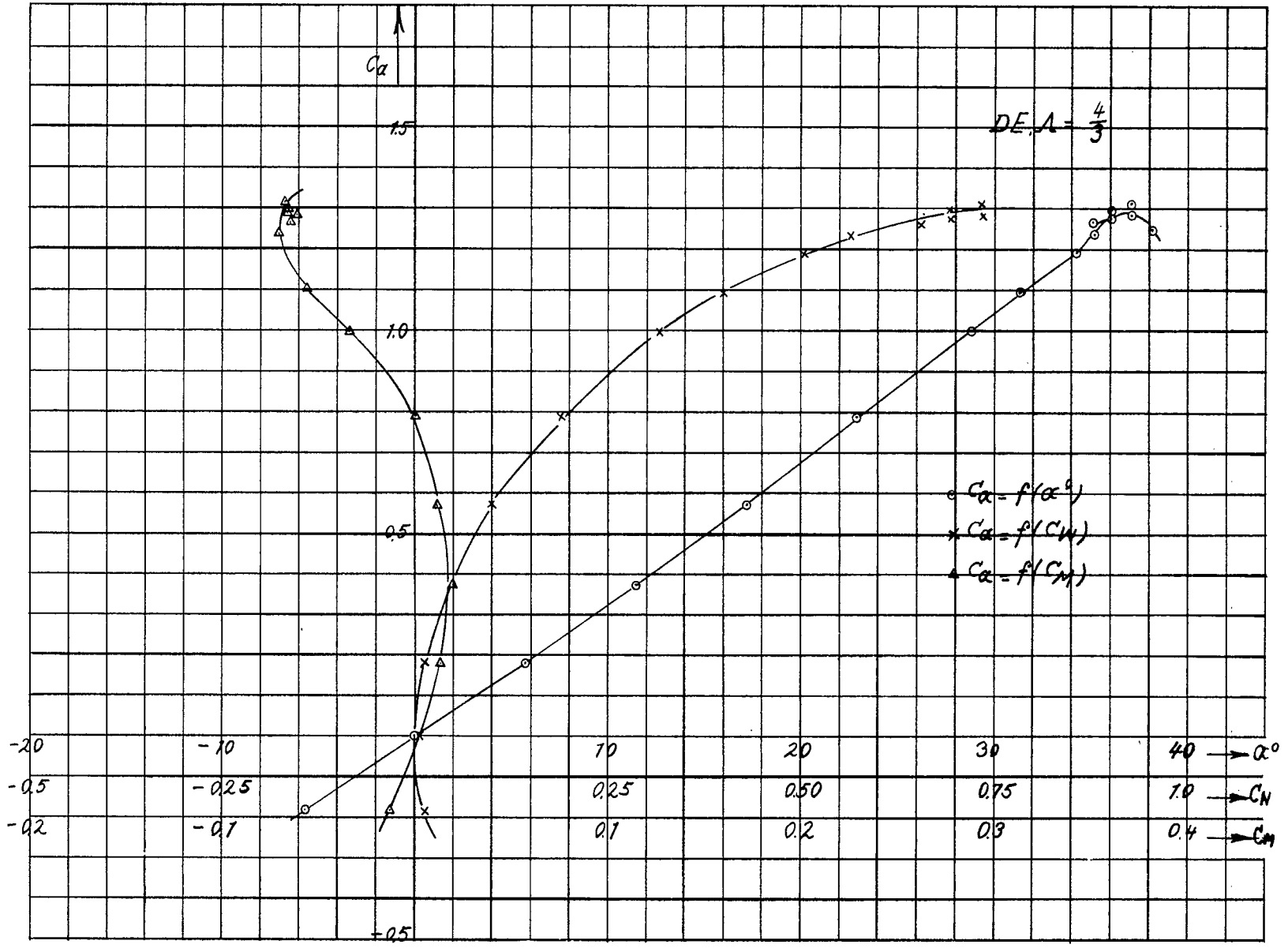


Chart 7. 3 - component measurements of a series of tapered wings (elliptic wing)

Table 5.

SIX-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WING

(Elliptic Wing)

TABLE NO. 6 TO CHARTS 8, 9

DE, $\Lambda = \frac{4}{3}$

$\alpha = 0$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	-0.0013	-0.0027	0.0061	-0.0010	0.0006	0.0024
-2	-.0013	-.0020	.0061	-.0009	.0006	.0019
0	-.0013	-.0003	.0060	-.0005	.0006	.0001
2	-.0013	.0007	.0060	-.0004	.0006	-.0010
4	-.0013	.0020	.0060	-.0004	.0006	-.0018
6	-.0013	.0027	.0065	-.0004	.0006	-.0019
10	-.0013	.0040	.0069	.0002	.0006	-.0025
15	-.0020	.0053	.0095	.0004	.0008	-.0023
20	-.0020	.0066	.0107	.0005	.0013	-.0026

DE, $\Lambda = \frac{4}{3}$

$\alpha = 9.43^\circ$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.3040	-0.0020	0.0316	-0.0194	0.0147	0.0067
-2	.3025	-.0020	.0317	-.0100	.0153	.0045
0	.3040	-.0020	.0317	.0002	.0150	.0014
2	.3040	-.0013	.0317	.0103	.0152	-.0017
4	.3040	-.0007	.0317	.0196	.0148	-.0039
6	.3000	-.0013	.0316	.0298	.0156	-.0054
10	.2960	-.0013	.0317	.0485	.0143	-.0092
15	.2840	-.0020	.0315	.0708	.0134	-.0138
20	.2730	-.0040	.0320	.0885	.0106	-.0158

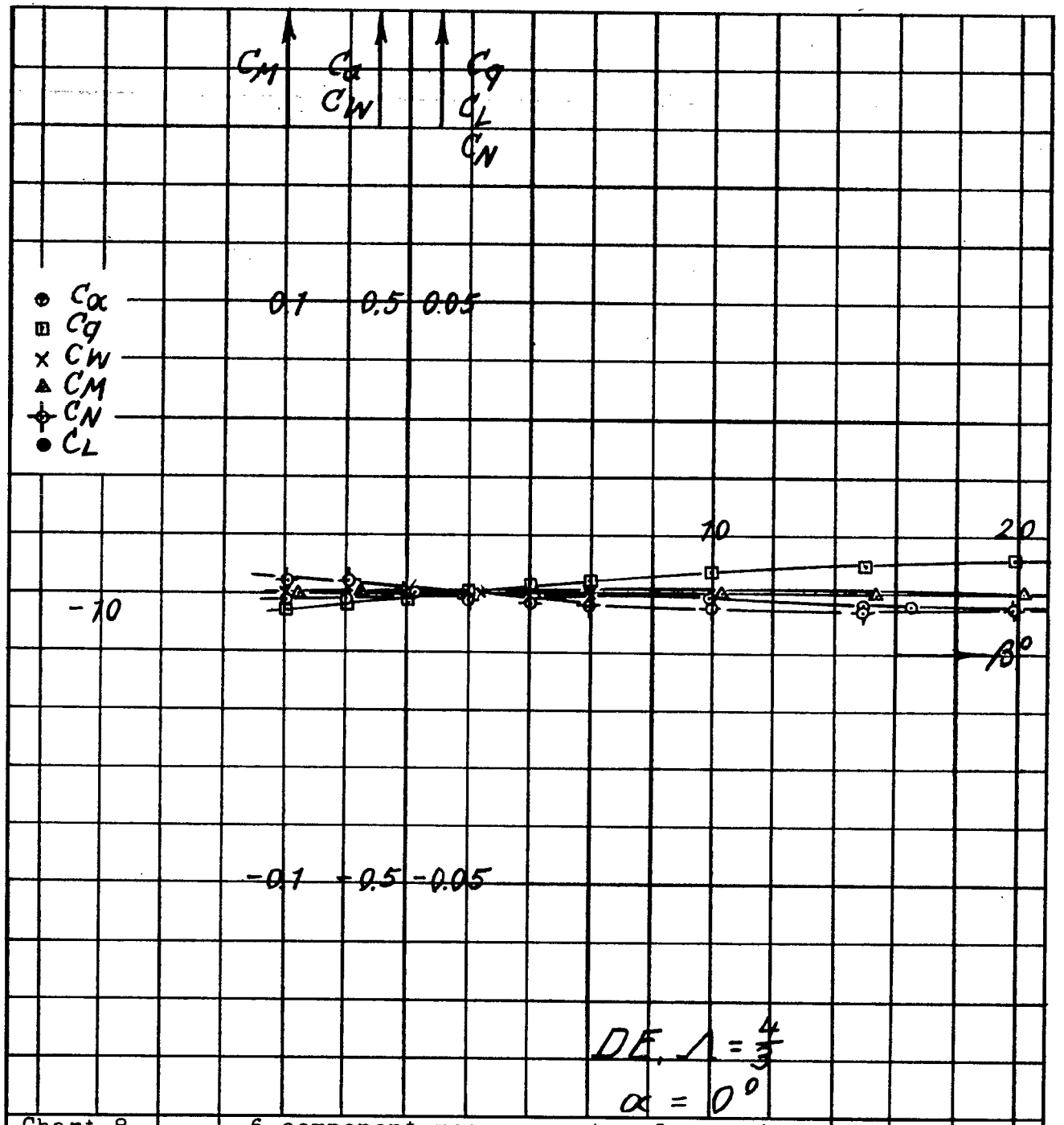


Chart 8.
Table 6.

6-component measurements of a series of tapered wings (elliptical)

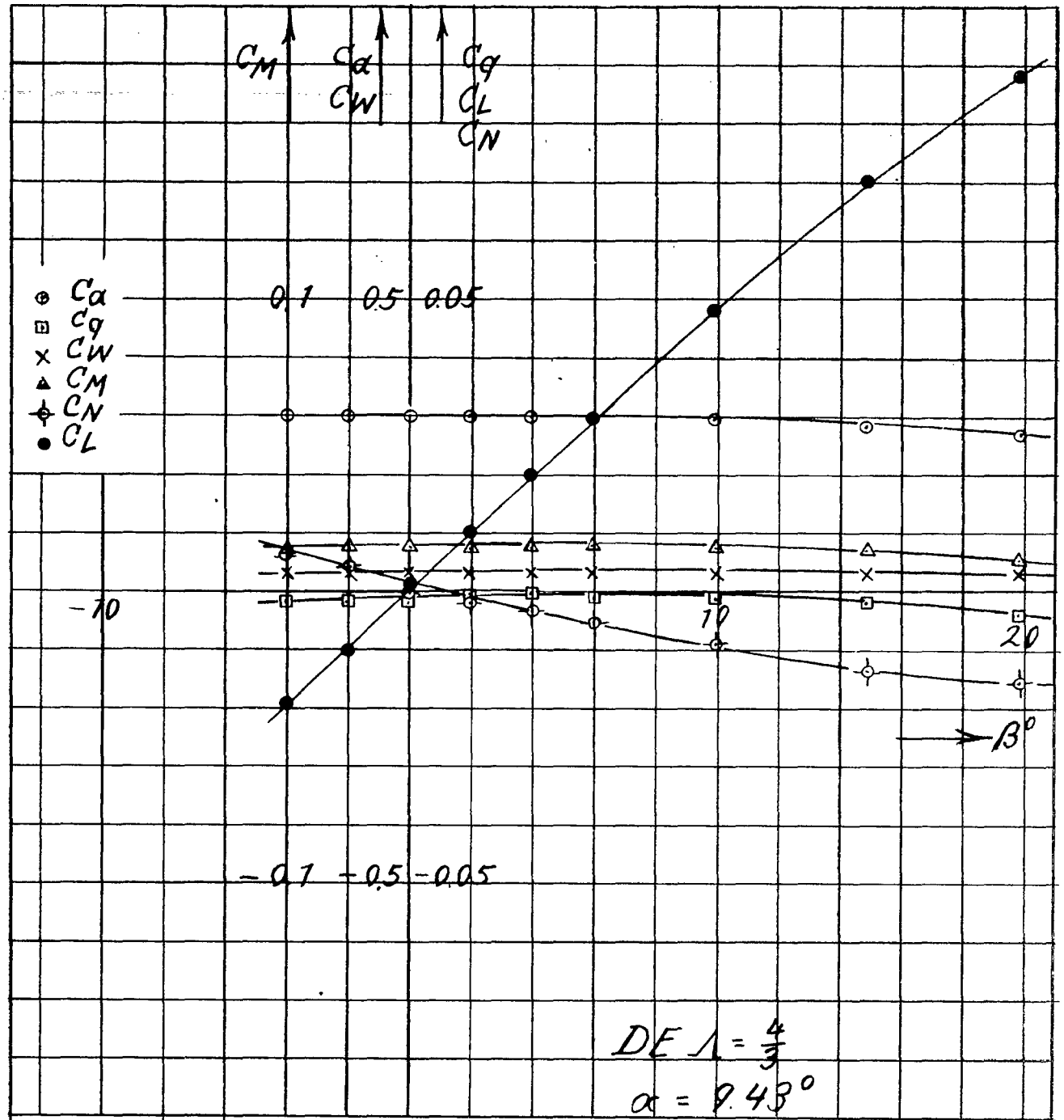


Chart 9.
Table 6.

6- component measurements of a series of tapered wings (elliptical)

SIX-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WING
(Elliptic Wing)
TABLE NO. 7 TO CHARTS 10, 11

DE, $\Lambda = \frac{4}{3}$

$\alpha = 17.95^\circ$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.6050	0.0050	0.1093	-0.0277	0.0085	0.0124
-2	.6050	.0020	.1091	-.0138	.0086	.0076
0	.6050	-.0020	.1091	.0022	.0090	.0015
2	.6040	-.0053	.1080	.0180	.0097	-.0039
4	.6040	-.0093	.1076	.0338	.0088	-.0081
6	.6000	-.0133	.1076	.0488	.0083	-.0123
10	.5890	-.0207	.1051	.0816	.0080	-.0211
15	.5720	-.0313	.1012	.1201	.0060	-.0326
20	.5480	-.0393	.0985	.1536	.0025	-.0450

DE, $\Lambda = \frac{4}{3}$

$\alpha = 25.89^\circ$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.9020	0.0213	0.2503	-0.0397	-0.0239	0.0184
-2	.9040	.0107	.2517	-.0199	-.0241	.0124
0	.9040	0	.2520	0	-.0241	0
2	.9040	-.0113	.2510	.0209	-.0236	-.0086
4	.9030	-.0227	.2503	.0391	-.0241	-.0149
6	.8940	-.0327	.2474	.0580	-.0228	-.0235
10	.8740	-.0533	.2412	.0932	-.0197	-.0372
15	.8580	-.0660	.2459	.1334	-.0203	-.0685
20	.8140	-.0707	.2440	.1510	-.0205	-.0889

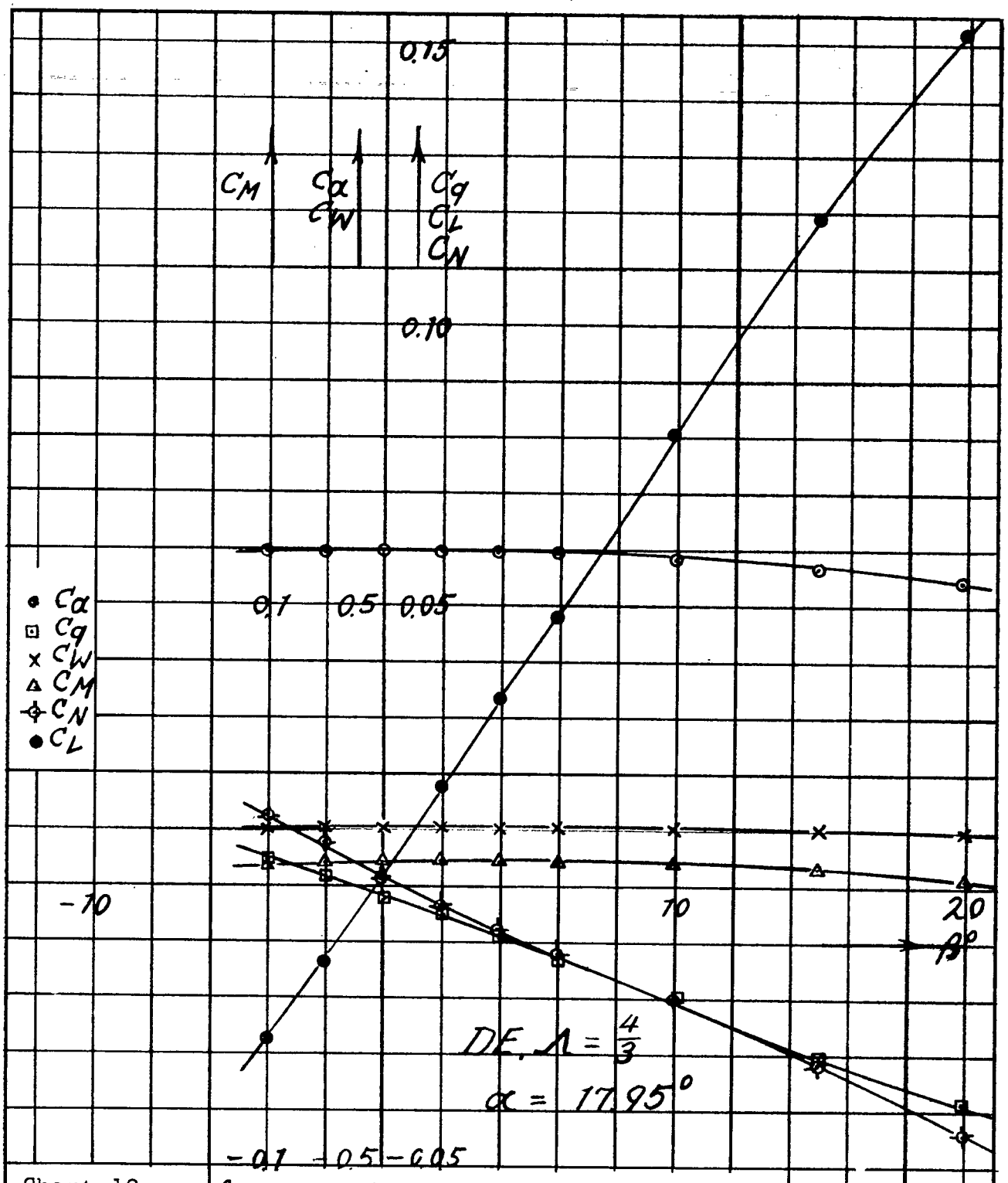


Chart 10. Table 7.

6-component measurements of a series of tapered wings (elliptical)

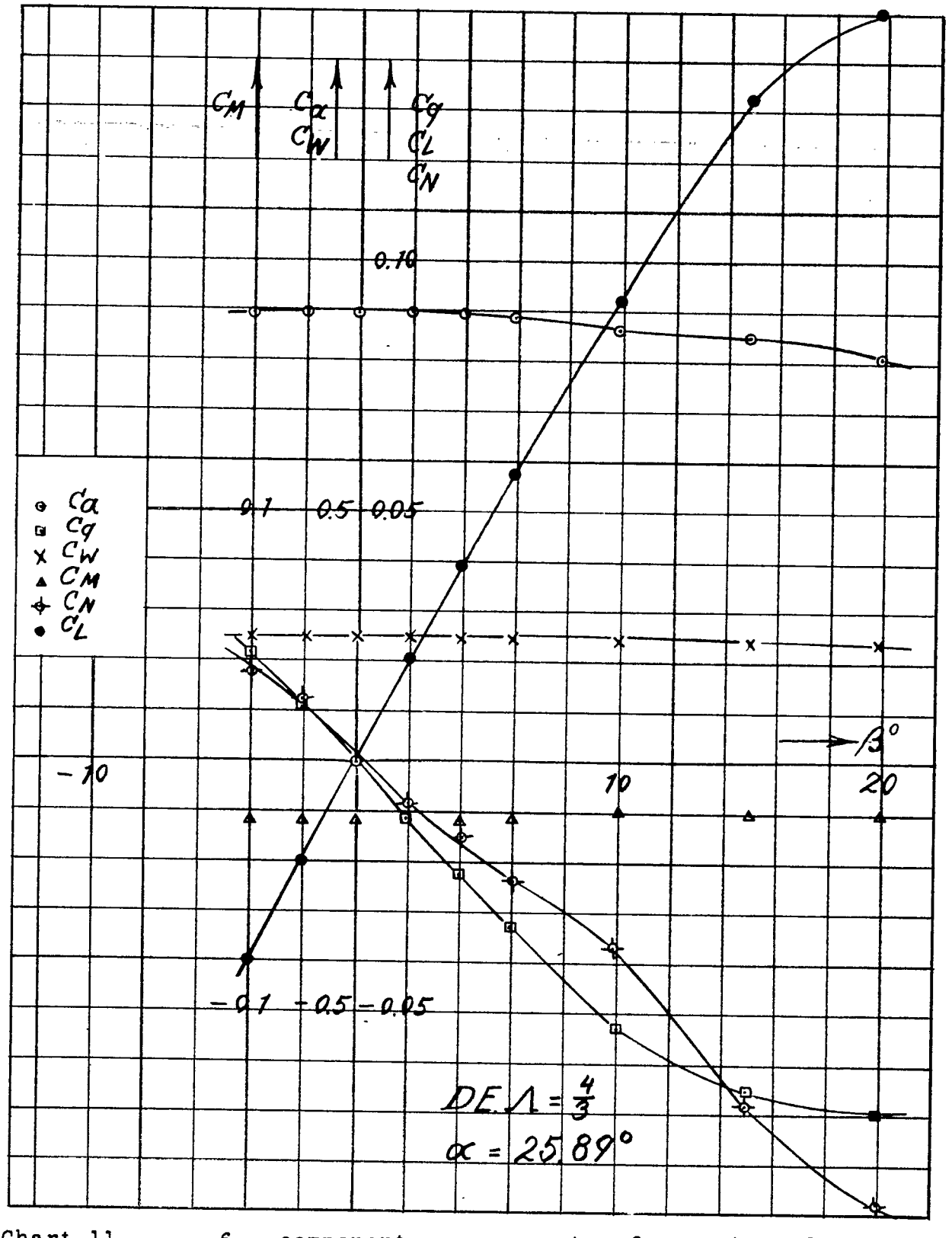


Chart 11. 6 - component measurements of a series of tapered wings (elliptic wing)

Table 7.

SIX-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WING

(Elliptic Wing)

TABLE NO. 8 TO CHART 12

DE, $\Lambda = \frac{4}{3}$

$\alpha = 35.47^{\circ}$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	1.2680	-0.0167	0.6387	-0.0074	-0.0662	0.0300
-2	1.2780	-.0087	.6355	-.0036	-.0659	.0183
0	1.2740	0	.6327	.0019	-.0667	.0028
2	1.2790	.0067	.6382	.0096	-.0669	-.0133
4	1.2710	.0120	.6369	.0159	-.0667	-.0284
6	1.2540	.0253	.6234	.0189	-.0692	-.0467
8	1.2310	.0133	.6198	.0299	-.0670	-.0593
10	1.2110	-.0013	.6194	.0378	-.0663	-.0655
12	1.1880	-.0100	.6127	.0465	-.0664	-.0719
15	1.1330	-.0247	.5982	.0519	-.0688	-.0718
20	.9840	-.0307	.5537	.0453	-.0824	-.0561

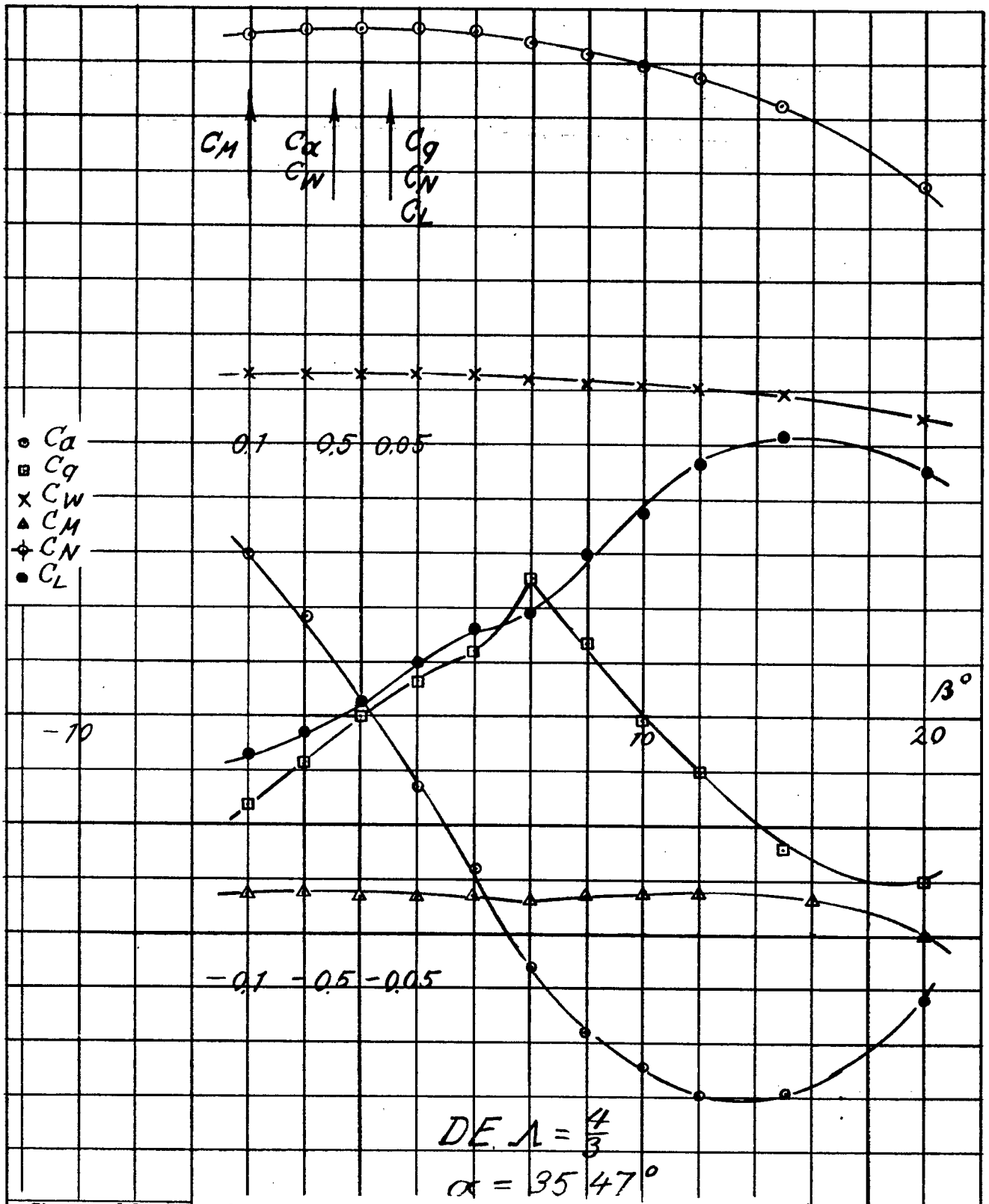


Chart 12.
Table 8.

6-component measurements of a series of tapered wings (elliptical)

THREE-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WING

(Elliptic Wing)

TABLE NO. 9 TO CHART 13

CE, $\Lambda = 1$

α^o	c_a	c_w	c_M
-5.80	-0.1600	0.0159	-0.0077
.01	-.0080	.0060	-.0006
5.83	.1386	.0137	.0104
11.63	.2959	.0393	.0111
17.41	.4691	.0886	0
23.16	.6612	.1748	-.0284
28.92	.8600	.3059	-.0664
31.81	.9465	.3826	-.0847
34.72	1.0160	.4703	-.0992
35.69	1.0440	.5017	-.1081
36.65	1.0710	.5348	-.1139
37.62	1.0930	.5677	-.1190
38.60	1.1110	.5991	-.1252
39.40	1.1270	.6326	-.1314
40.56	1.1440	.6747	-.1371

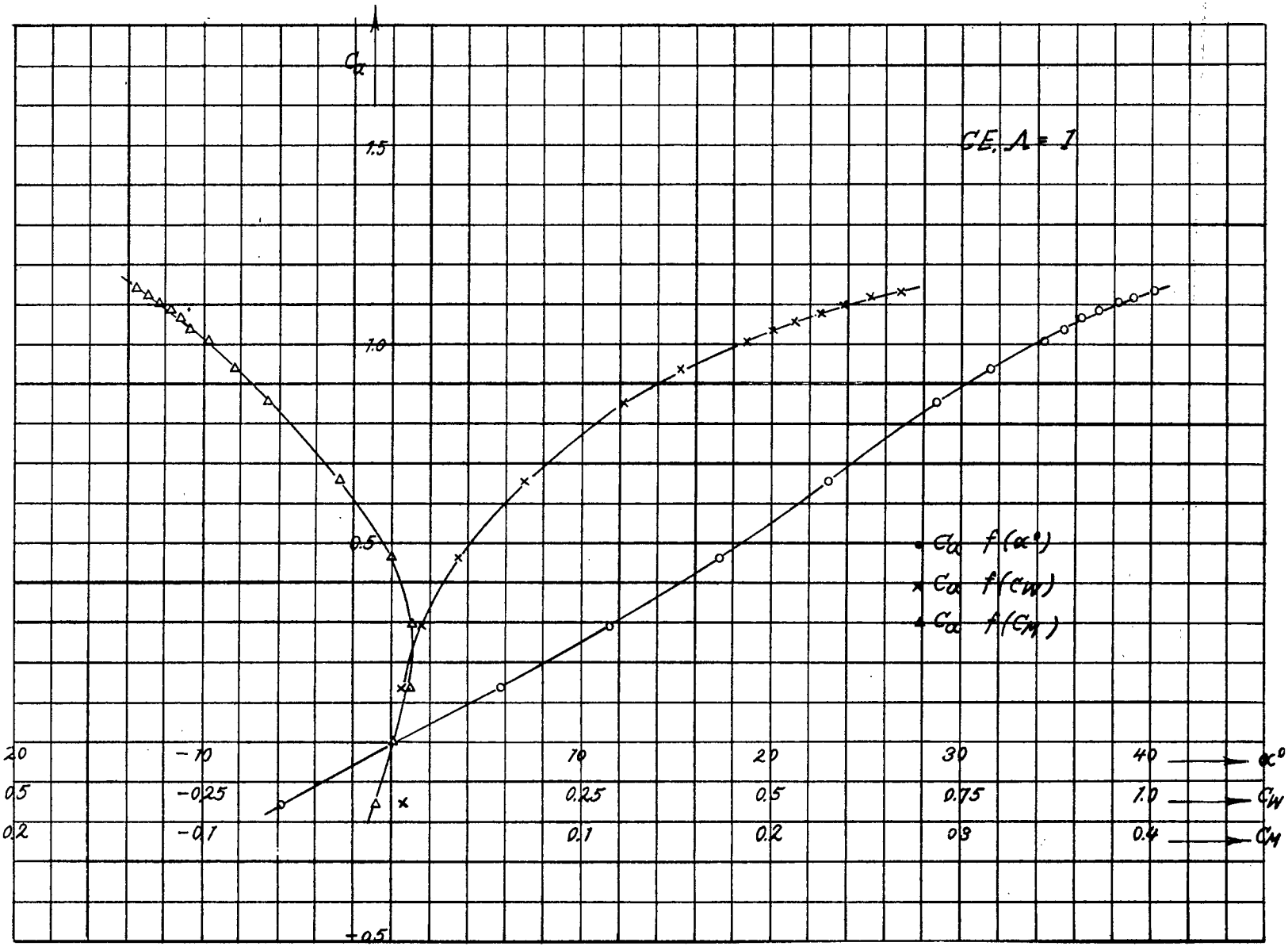


Chart 13. 3 - component measurements of a series of tapered wings (elliptic wing)

Table 9

SIX-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WING

(Elliptic Wing)

TABLE NO. 10 TO CHARTS 14, 15

CE, $\Lambda = 1$

$\alpha = 0.4^\circ$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.0013	-0.0033	0.0067	-0.0001	-0.0044	0.0014
-2	.0013	-.0013	.0061	0	-.0046	.0002
0	.0013	0	.0060	0	-.0046	-.0002
2	.0013	.0013	.0063	0	-.0046	-.0006
4	.0013	.0027	.0065	.0001	-.0046	-.0009
6	.0013	.0027	.0069	.0002	-.0045	.0001
10	.0013	.0040	.0083	.0002	-.0045	.0011
15	.0013	.0067	.0093	.0015	-.0045	.0015
20	.0013	.0080	.0108	.0016	-.0045	.0029

CE, $\Lambda = 1$

$\alpha = 11.73^\circ$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.2974	0.0013	0.0393	-0.0226	0.0111	0.0038
-2	0.2974	.0007	.0391	-.0129	.0119	.0014
0	.2974	0	.0391	0	.0116	-.0006
2	.2974	-.0007	.0388	.0129	.0113	-.0030
4	.2960	-.0020	.0391	.0248	.0117	-.0037
6	.2935	-.0033	.0388	.0378	.0122	-.0047
10	.2908	-.0053	.0391	.0605	.0109	-.0072
15	.2855	-.0113	.0395	.0878	.0086	-.0061
20	.2800	-.0133	.0383	.1103	.0044	-.0070

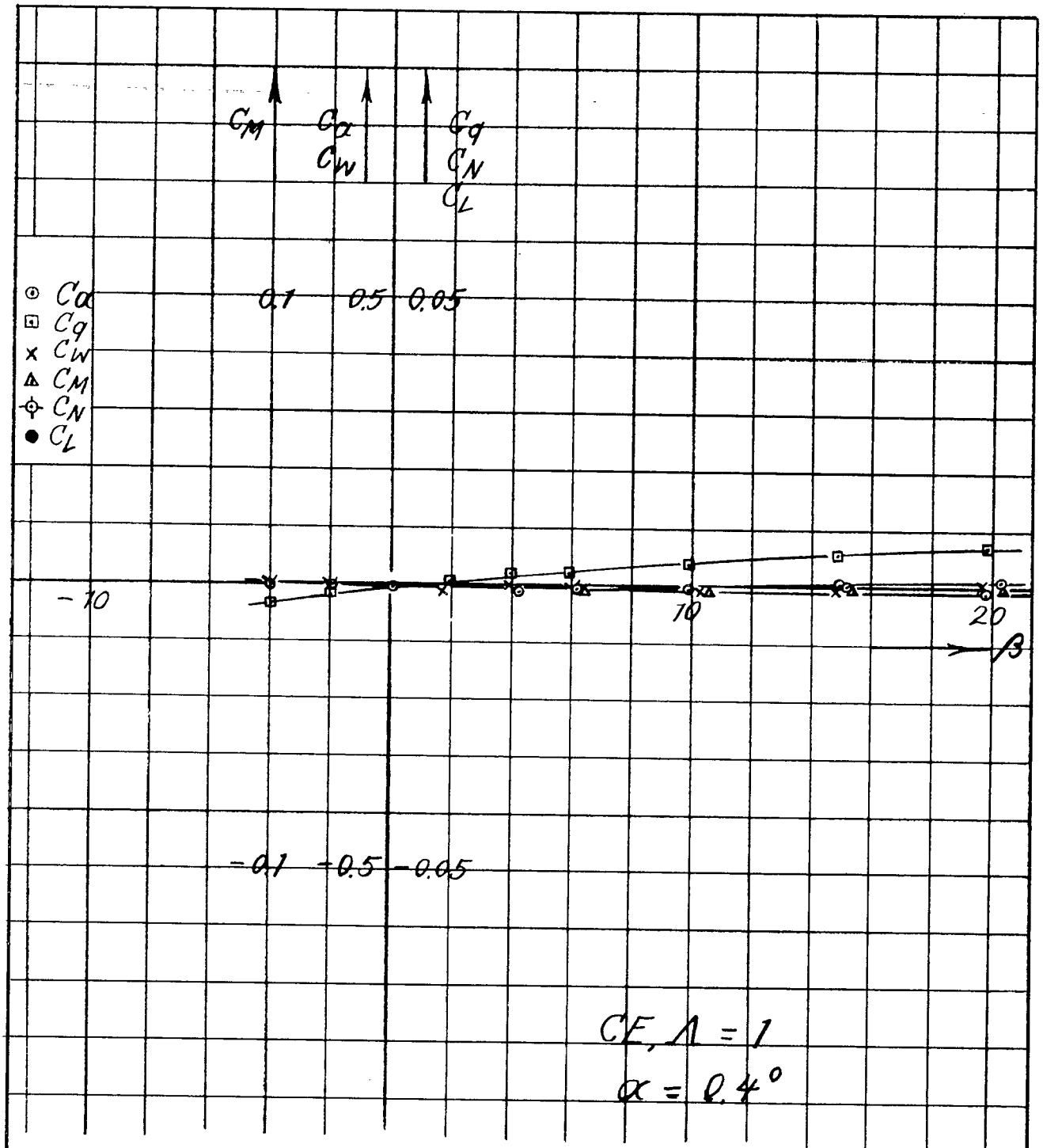


Chart 14. 6-component measurements of a series
Table 10. of tapered wings (elliptical)

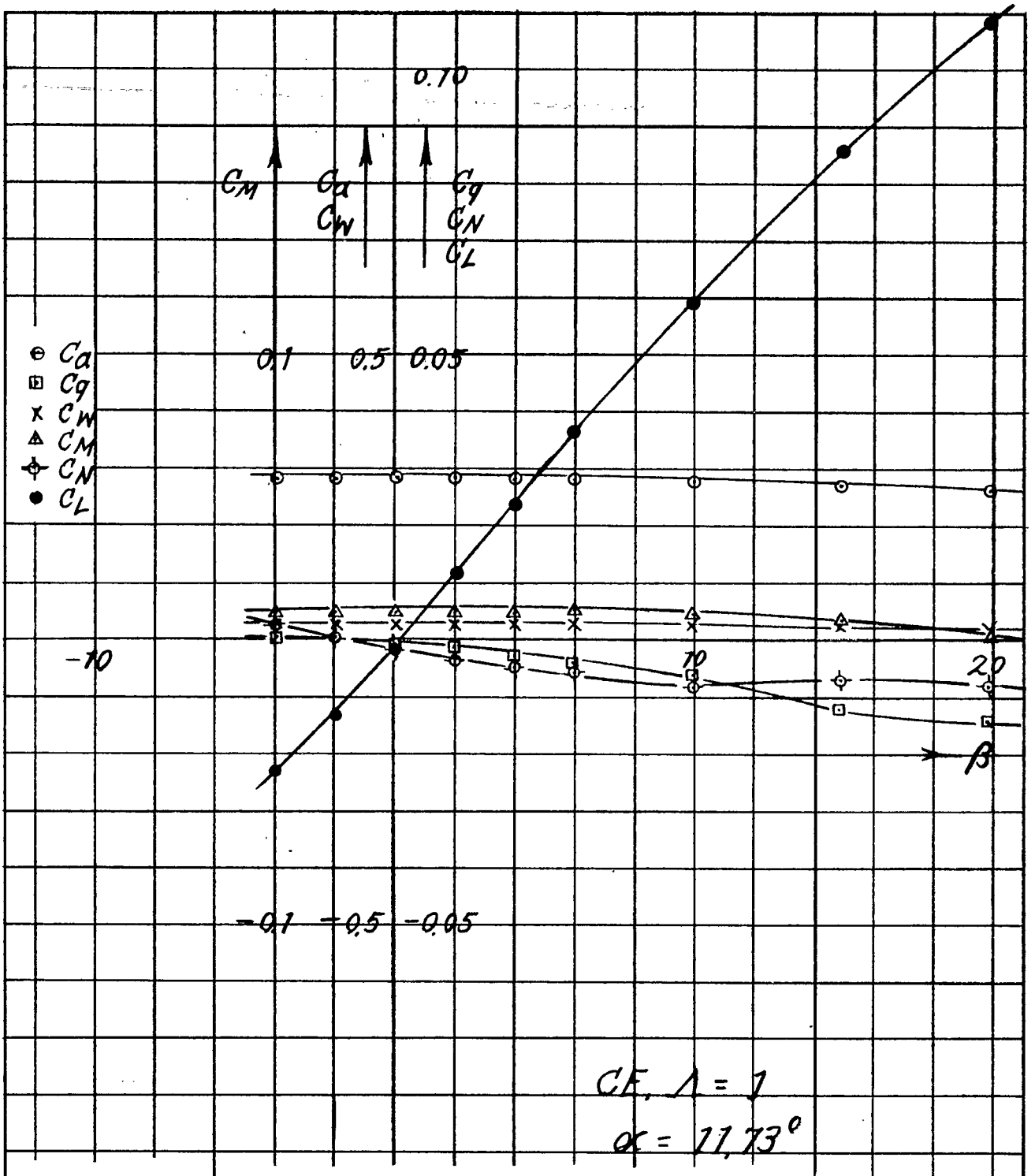


Chart 15.
Table 10.

6-component measurements of a series of tapered wings (elliptical)

SIX-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WING

(Elliptic Wing)

TABLE NO. 11 TO CHARTS 16, 17

CE, $\Lambda = 1$

$\alpha = 21.36^\circ$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.5960	0.0113	0.1429	-0.0327	-0.0185	0.0082
-2	.5980	.0047	.1436	-.0128	-.0181	.0040
0	.6000	-.0013	.1435	.0025	-.0190	.0003
2	.5990	-.0060	.1433	.0153	-.0182	-.0044
4	.5980	-.0120	.1423	.0340	-.0188	-.0085
6	.5960	-.0207	.1416	.0544	-.0190	-.0118
10	.5850	-.0374	.1367	.0982	-.0173	-.0169
15	.5740	-.0588	.1312	.1469	-.0189	-.0236
20	.5660	-.0781	.1273	.1854	-.0220	-.0334

CE, $\Lambda = 1$

$\alpha = 30.3^\circ$

β°	c_a	c_q	c_w	c_L	c_M	c_N
-4	0.8920	0.0280	0.3383	-0.0445	-0.0718	0.0229
-2	.8940	.0120	.3424	-.0226	-.0732	.0137
0	.8990	-.0053	.3422	.0017	-.0744	.0019
2	.8990	-.0213	.3412	.0256	-.0742	-.0076
4	.8930	-.0380	.3374	.0510	-.0717	-.0153
6	.8860	-.0513	.3309	.0709	-.0691	-.0254
10	.8750	-.0860	.3221	.1169	-.0675	-.0372
15	.8330	-.1159	.2987	.1758	-.0612	-.0626
20	.8000	-.1431	.2799	.2259	-.0610	-.0835

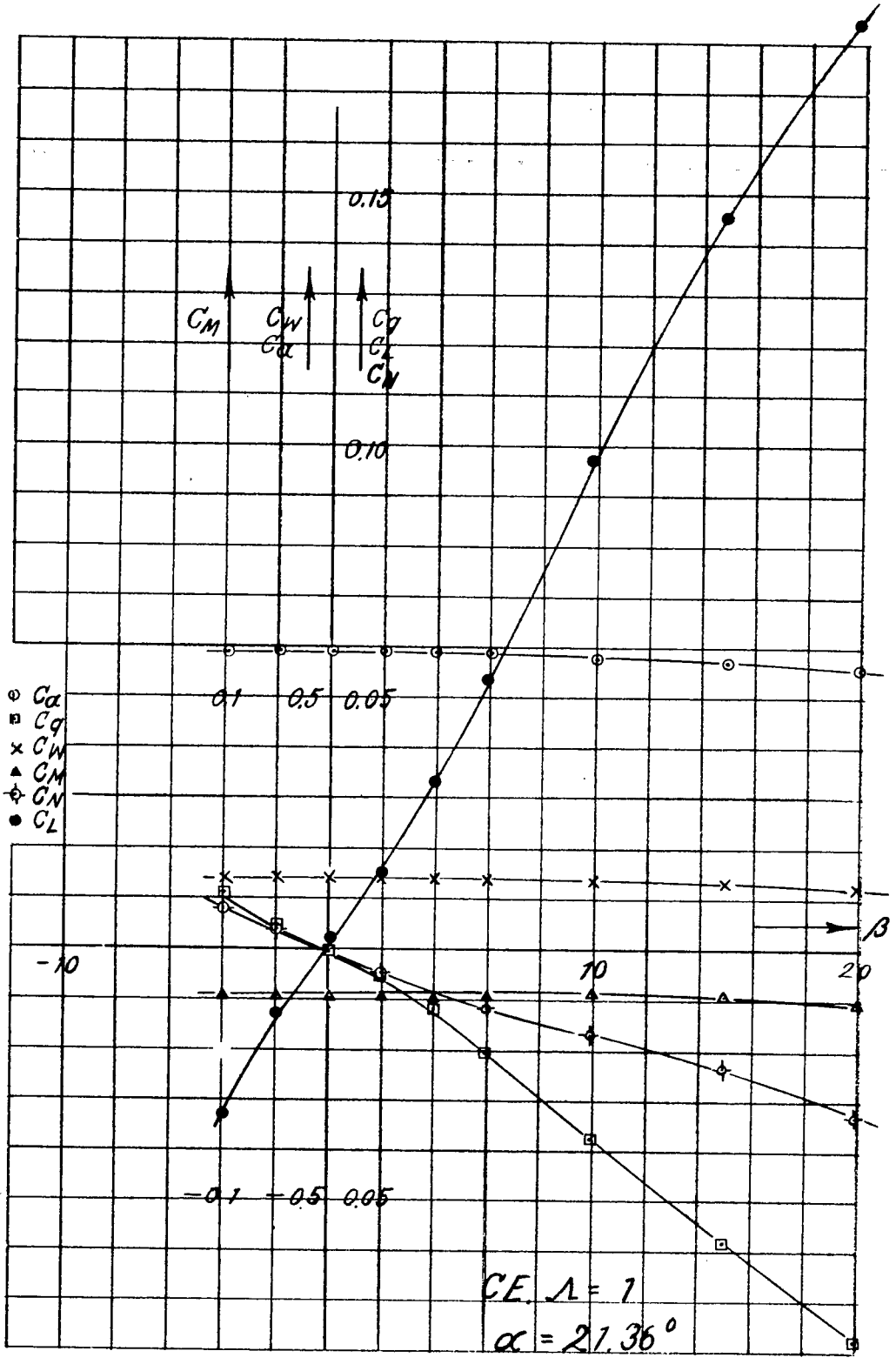


Chart 16. 6 - component measurements of a series of tapered wings (elliptic wing)

Table 11.

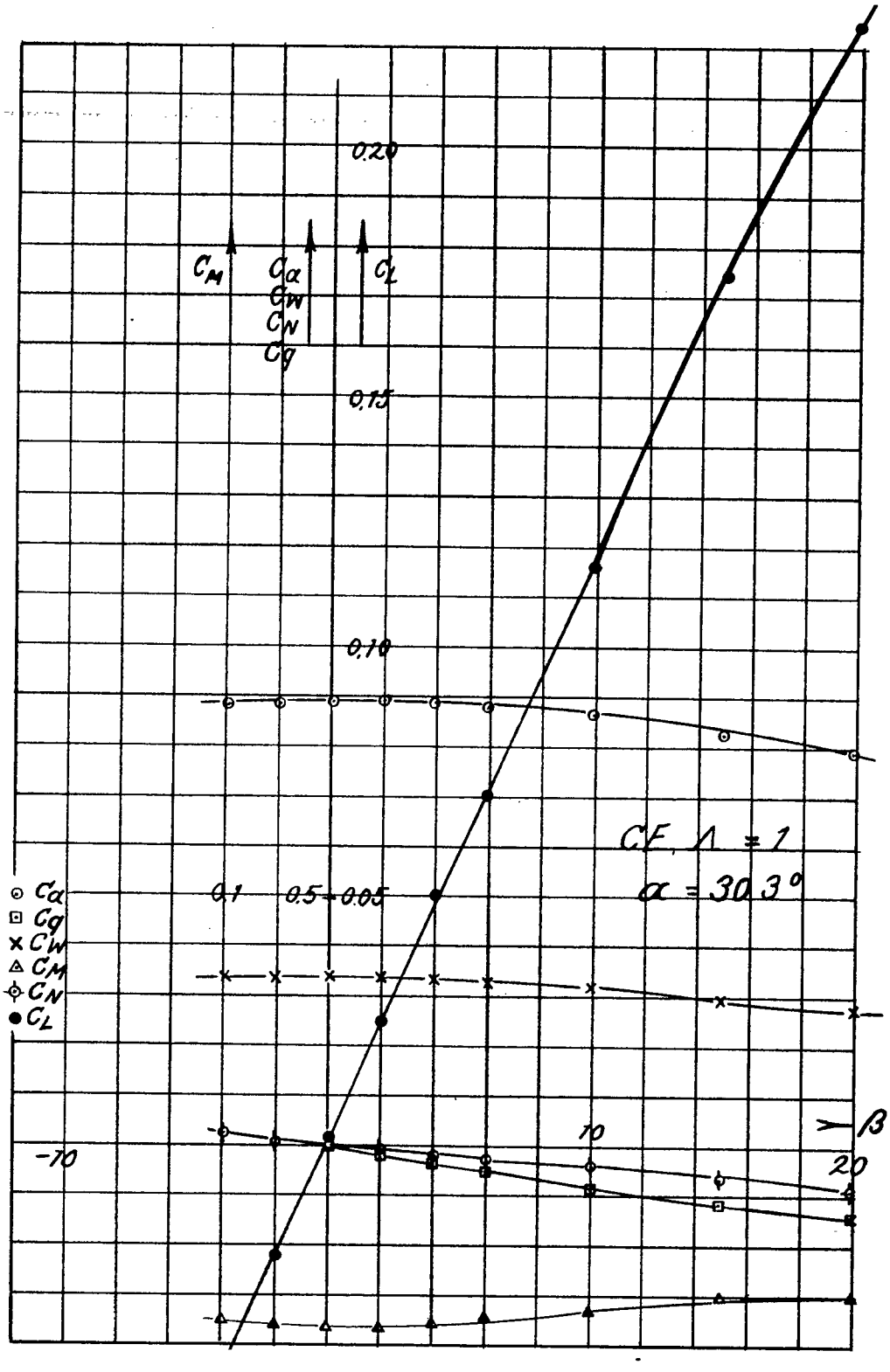


Chart 17. 6 - component measurements of a series of tapered wings (elliptic wing)

Table 11.

SIX-COMPONENT MEASUREMENTS OF A SERIES OF TAPERED WING

(Elliptic Wing)

TABLE NO. 12 TO CHART 18

CE, $\Lambda = 1$

$\alpha = 38.63°$

β^o	c_a	c_q	c_w	c_L	c_M	c_N
-4	1.1110	0.0394	0.6028	-0.0387	-0.1260	0.0357
-2	1.1110	.0167	.6053	-.0198	-.1263	.0203
0	1.1150	-.0040	.6042	.0015	-.1266	.0014
2	1.1130	-.0254	.6037	.0232	-.1267	-.0135
4	1.1090	-.0487	.5989	.0435	-.1264	-.0285
6	1.1050	-.0720	.5921	.0650	-.1247	-.0412
10	1.0790	-.1167	.5724	.1027	-.1181	-.0634
15	1.0370	-.1620	.5454	.1522	-.1104	-.0976
20	.9830	-.2066	.5087	.1927	-.1028	-.1191

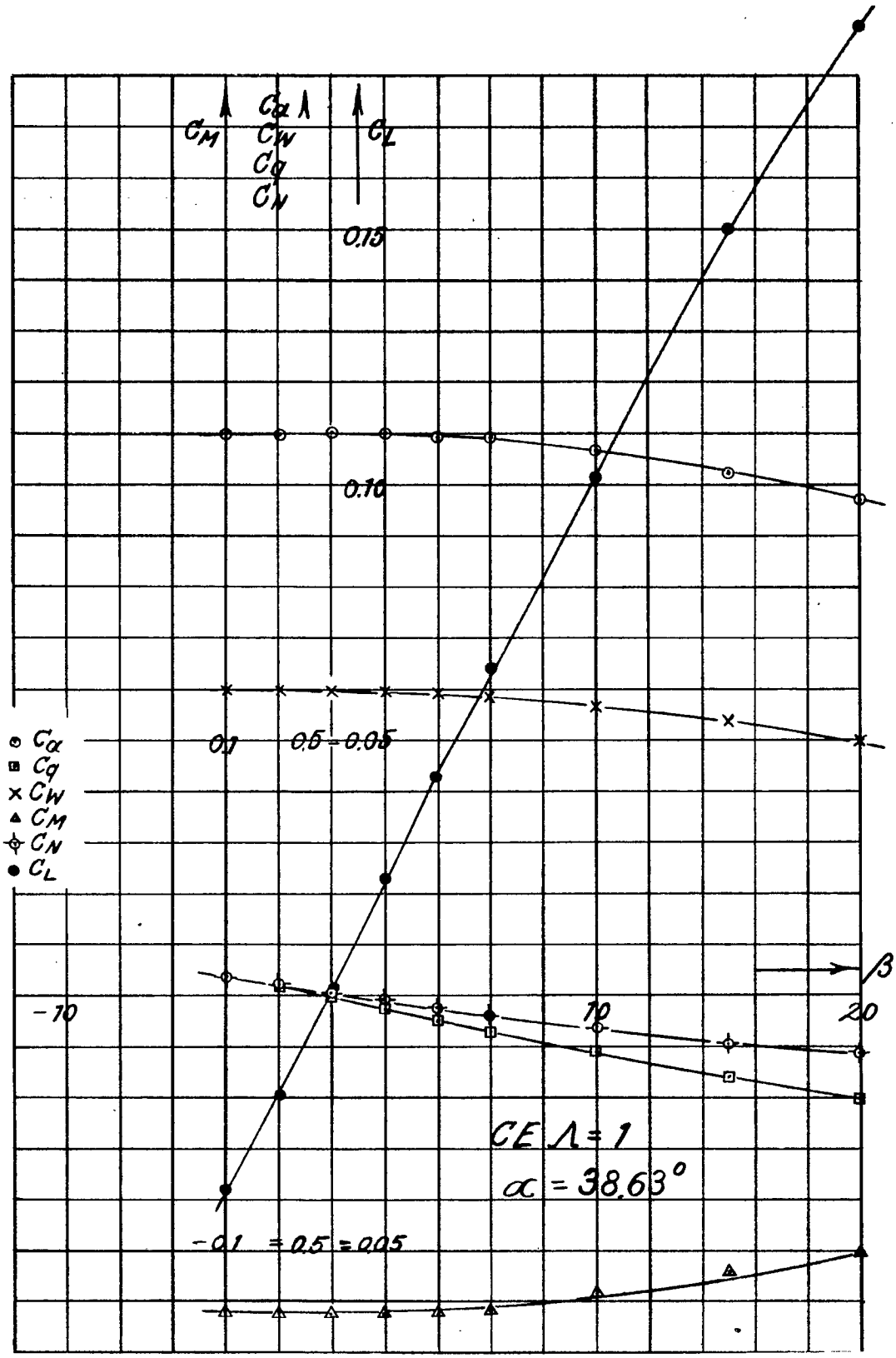


Chart 18. 6 - component measurements of a series of tapered wings (elliptic wing)

Table 17.

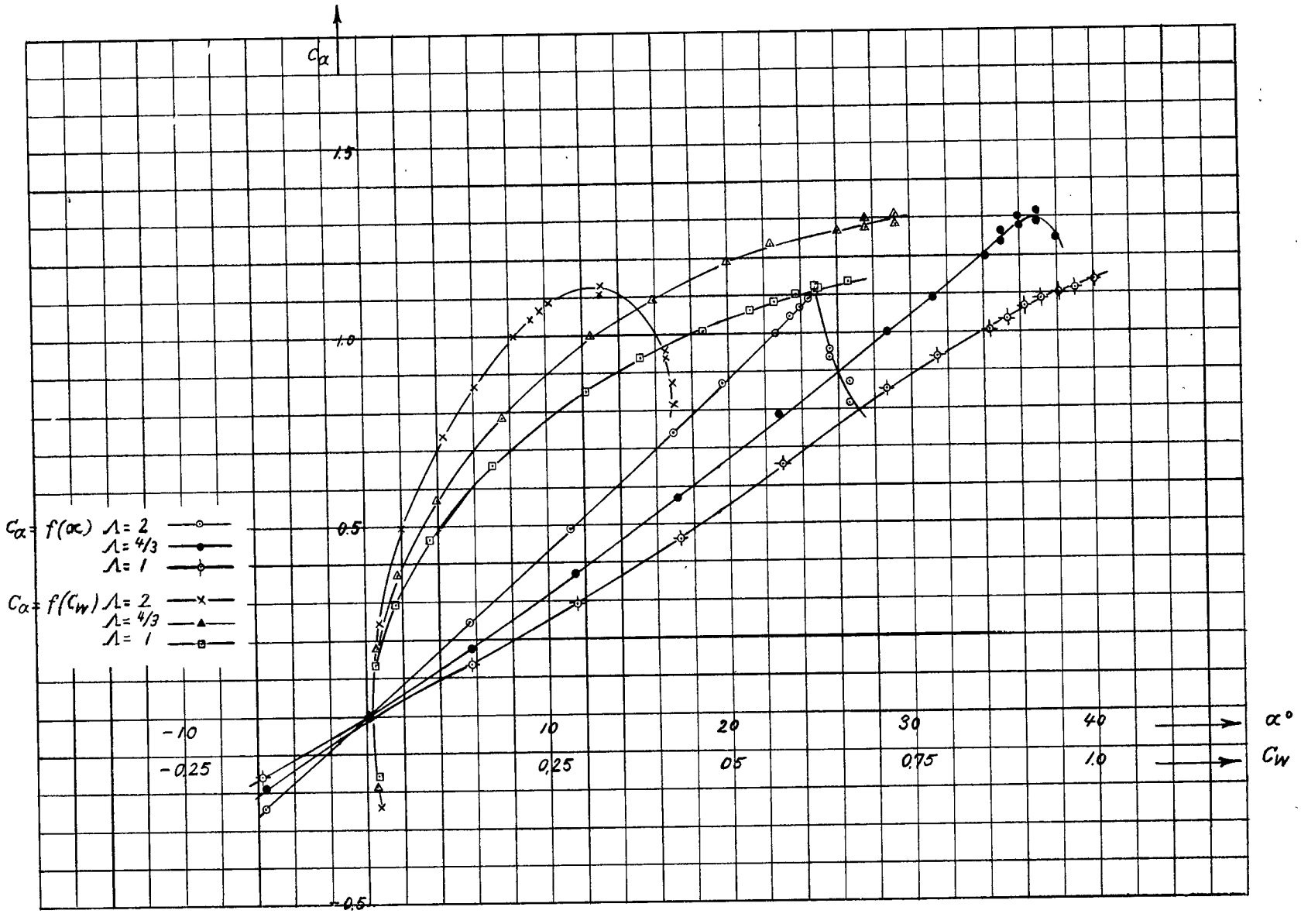


Chart 19. $c_a = f(\alpha)$ - and $c_a = f(c_w)$- curves of the series of elliptic wings.

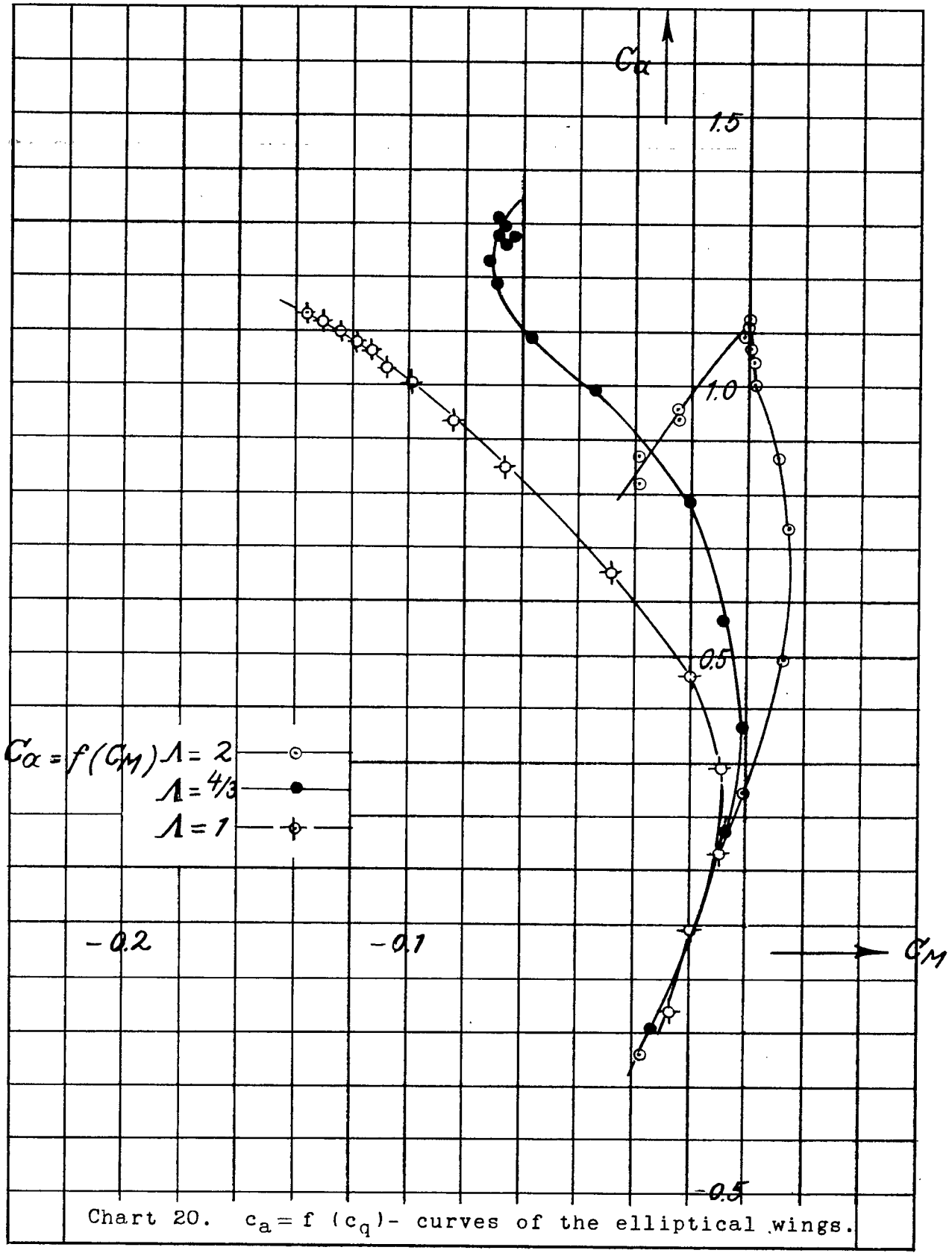


Chart 20. $c_a = f(c_q)$- curves of the elliptical wings.

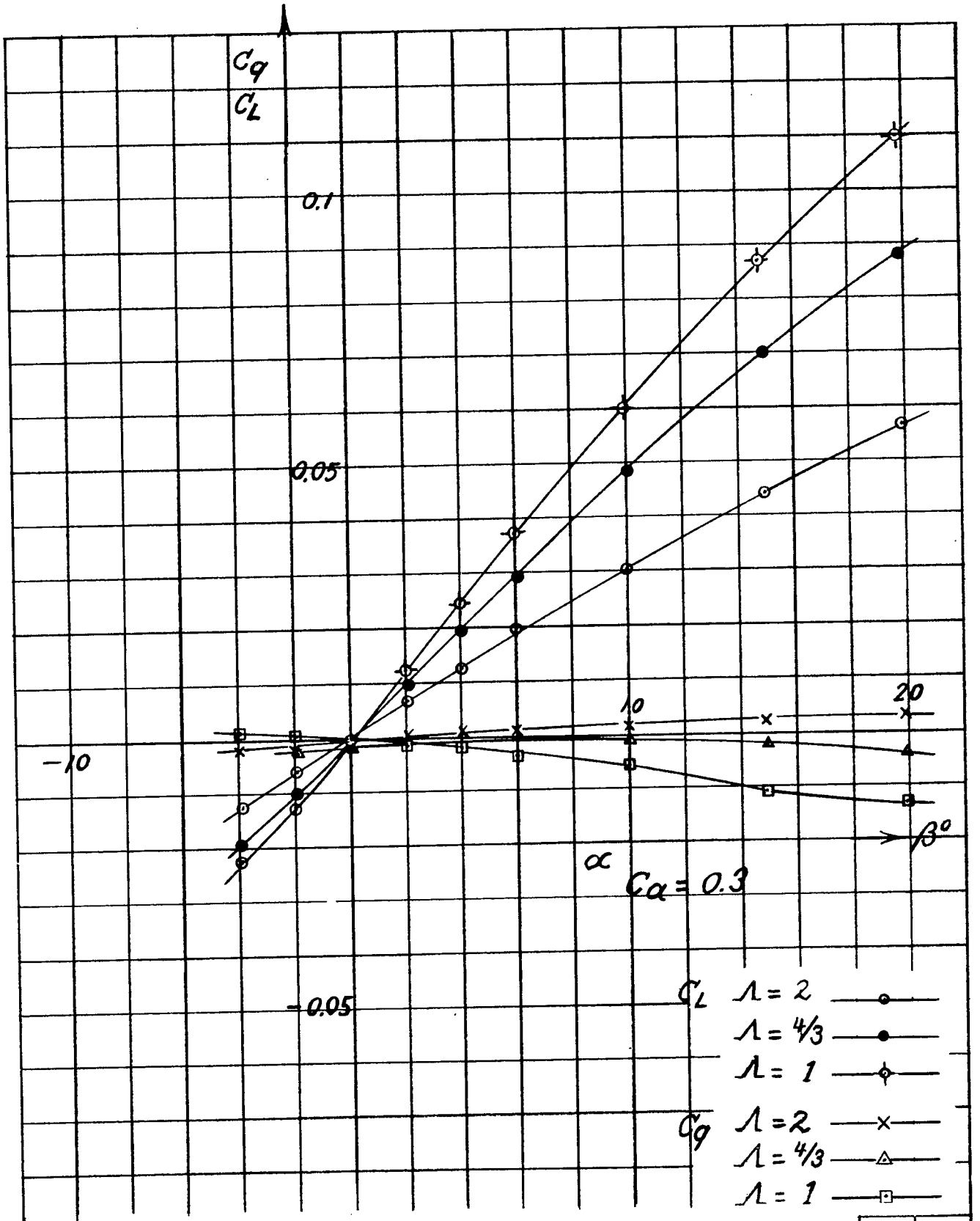


Chart 21. c_L-and c_q curves of the series of elliptical wings.

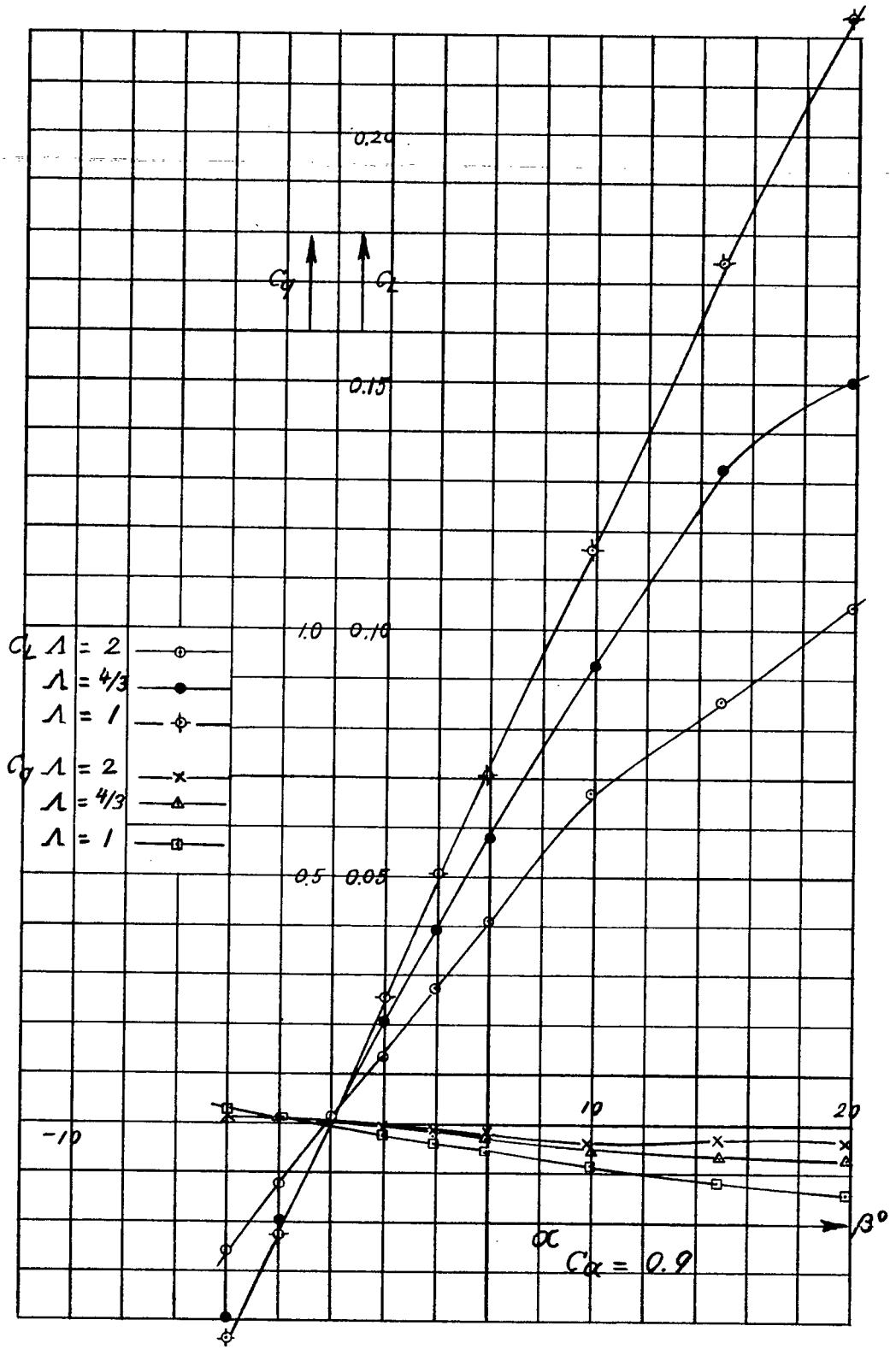


Chart 22. c_L-and c_q- curves of the series of elliptic wings.

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